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THE DEVELOPMENT OF SOVIET NONFERROUS METALLURGY

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## THE DEVELOPMENT OF SOVIET NONFERROUS METALLURGY

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## 1. The Development of the Nonferrous Metals Processing Industry

[This is a translation of an article written by M. F. Bazhenov in Byulleten' Tsvetnoy Metallurgii (Bulletin of Nonferrous Metallurgy), No 19/20 (96-97), 1957, pages 83-87.]

The growth of all branches of industry after the Great October Socialist Revolution was accompanied by a signal rise in the demand for various types of rolled products from nonferrous metals and alloys. The nonferrous metals processing industry acquired considerable importance.

Rolled products from nonferrous metals and alloys are a component part of many machines, assemblies, apparatuses, instruments and devices. The broad use of rolled products and alloys stems from the specificity of the requirements necessary for the performance of individual units and parts of machines, apparatuses and instruments. Such requirements pertain to high anti-corrosion properties together with high strength characteristics of the material, high electric conductivity or electric resistance, and heat resistance.

A considerable amount of nonferrous products in the form of brass and copper strips is applied in the automobile and aviation industries in the manufacture of pipes for the radiators of tractors, cars and propeller aircraft, and in the form of brass plates, copper sheets and pipes, and plumbous brass rods in chemical equipment building.

The manufacture of steam turbines requires many brass and cupronickel pipes. Pipes of copper and rods of manganous brass and stannous and manganese-silicate bronzes find widespread application in shipbuilding. Sheets of monel metal are used for oil-filled cables. Rods of plumbous brass are applied in instrument building and as parts of machine tools and medical equipment; aluminum, beryllium and manganese-silicate bronzes, constituting a spring material that displays, in addition to high elastic properties, a satisfactory corrosion resistance, are applied in instrument building; argentan and cupronickel alloys, which display high corrosion resistance and serve as good bases for decorative coatings (nickel- and silver-plating), are used in the production of table ware and restaurant fixtures; aluminum bronze and cupronickel, which display high plastic and anti-corrosion properties, are used in the minting of coins.

This list could be extended much further.

## The Smelting and Casting of the Ingots of Nonferrous Metals and Alloys

The technology of smelting, which is the initial stage in the manufacture of rolled products from nonferrous metals and alloys, has traversed a long and involved path of development during the past forty years. In prerevolutionary times the smelting of nonferrous metals was carried out in shaft crucible furnaces fired with coke and mazut or in flame-contact reverberatory furnaces. Only as late as in 1927 did low-frequency electric induction furnaces with power ratings of 120 to 160 kva and capacities of 300 to 600 kilograms, begin to appear, with all the concomitant radical changes in the technology of the smelting of nonferrous metals.

Upon the transition to electric smelting the weight of the ingot climbed from 80 to 180-240 kilograms, reaching one ton at present. The perfecting of electric furnaces was achieved by altering the number of ducts (two- and three-duct furnaces had appeared), increasing the power rating and capacity, and the strength of the lining, and employing water-cooled coils. At present, furnaces with a power rating of up to 1,100 kva and capacities of up to 1,200 - 5,000 kilograms are in operation, and the construction of electric-smelting induction furnaces with capacities of up to 15 tons is envisaged for the immediate future. The productivity of these furnaces has risen from 16-18 tons daily in 1927 to 70-85 tons daily in 1957. Their durability has also improved drastically: while previously they could smelt 400 to 600 tons of brass each (before repair) now they can smelt up to 4,000 tons and more (before repair). While previously small electric furnaces used to be charged by hand, at present, in connection with the increase in their power ratings and capacity, this operation has been mechanized.

The employment of low-frequency induction furnaces proved to be insufficiently convenient and profitable for smelting a number of metals and alloys, especially the difficultly fusible ones. For instance, till this very day, the durability of these furnaces when used to smelt nickel, does not exceed 120 to 200 tons. Therefore, work is in progress to perfect their design, and high-frequency induction furnaces with capacities raised from 80 to 500 kilograms are being introduced.

The rise in requirements regarding the quality of ingots and rolled products, especially by the electrical engineering, radio engineering and electrical vacuum in-



dustries, had led to the devising of high-frequency vacuum induction furnaces ensuring the production of ingots of highly pure metals not saturated with gases and impurities. By now there exist high-frequency vacuum furnaces with capacities of up to 500 kilograms, ensuring the smelting and casting of ingots in a vacuum of up to  $10^{-1}$ -- $10^{-2}$  millimeters of the mercury column.

However, these furnaces display major shortcomings: in particular, their extremely low natural power factor, which entails the necessity of installing a great number of static capacitors, which, in turn, requires considerable space and capital expenditures. The operation of vacuum furnaces involves high losses of electricity. These circumstances necessitate the conduct of studies for further perfecting of these furnaces; in particular, the drafting and development of new designs of ductless industrial-frequency (50-period) furnaces with capacities of up to three tons.

At present, it is deemed most rational to smelt in electric furnaces not only brass and other copper-base alloys but also copper. The copper is smelted with minimal expenditures of electrical energy in electric arc furnaces. When copper is smelted in induction furnaces, the irrecoverable losses of metal are reduced to a minimum. As for the mazut-burning flame furnaces, at present they are used merely to resmelt and refine copper scrap and wastes.

The employment of rolled products from diverse multi-component complex alloys of nonferrous metals (aluminum-iron-manganese and aluminum-iron-nickel bronzes, and other alloys), and the necessity of an accurate observance of the desired composition while blending the alloy charge and the necessity of obtaining highest-quality ingots, have led to the expansion of production and the employment of alloying elements, which has also improved the technology of smelting,

The development of the technology of smelting nonferrous metals was also accompanied by improvements in the ingot-casting technology.

During the last 40 years considerable labors were executed in improving the composition of the furnace-lining materials and of the coating and chemically aggressive fluxes. This has made it possible to raise the quality of the smelting of nonferrous metals, reduce losses and restrict substantially the saturation of metals by gases and impurities.

Measures were worked out for casting ingots under conditions ensuring the obtainment of quality-grade melts and ingots (without surface flaws, and without gas-caused porosity and shrinkage friability), with a satisfactory

crystal structure and with the necessary mechanical properties conducive to the subsequent normal deformation of the metal. Previously ingots were cast into iron molds of various geometrical shapes and dimensions. The quality of ingots used to be low. At present, iron molds are no longer commonly used. As of 1930, vertical molds with water-cooled sheets and corner plates and horizontal molds with a cast-iron frame and water-cooled copper bottom plate and topside electric heater began to be used. This ensured a definite crystallization of the ingot and improved its quality considerably. However, such a method of casting did not guarantee the obtainment of ingots of an irreproachable quality, and casting experts had continued to labor on exploring new and better methods. Thus, the semicontinuous method of casting, carried out in a cooled crystallizer with a sliding bottom, began to be applied initially for casting aluminum and its alloys -- and later on (as of 1950), for casting heavy nonferrous metals and alloys. The employment of the semicontinuous casting of the ingots of heavy nonferrous metals led to a radical change in the technology of ingot casting. The introduction of the semicontinuous and the more perfect continuous casting of ingots results in a substantial improvement in the quality of ingots (especially bronze), increase the yield of acceptable metal, reduction in losses, and increase in the productivity of labor and equipment, and it ensures the possibility of the mechanization and automation of the entire production cycle.

At present, approximately six percent of all ingots of heavy nonferrous metals and alloys is being cast by the semicontinuous method, and in the years 1962-1963 this figure should climb to 70-80 percent.

There also appeared other useful and novel methods of casting ingots of relatively minute weight. These include the method of vacuum suction (developed by a docent of Sverdlovsk Polytechnic Institute, Comrade Ksenofontov), and the method of jetless casting. The former method serves to obtain ingots of up to 80-100 millimeters in diameter and up to 900-1,000 millimeters in length, with a satisfactory surface and with a limited amount of wastes in the form of cut-off ends. This method has served to master the casting of phosphorous-tin bronze, tombac and grade-L62 brass.

The charge-preparing operations in the electro-casting and casting shops are of great importance in the production of ingots; these operations also have been systematically perfected by installing in charge shops equipment for sizing and blending the charge (cabbaging and briquetting

presses, magnetic separators, guillotine, disk and alligator shears, etc.). In the immediate future it will be necessary to mechanize and automate completely the charge-preparing processes by installing computers for the automatic selection of charge versions according to a given chemical composition (inclusive of impurities), bins for storing charge, automatic suspension trolleys, and other necessary equipment.

The hulling of rough ingots and their preparation for further treatment by deformation have been improved owing to the increase in cutting speeds, replacement of scouring machines by milling machines, and the installation of automatic lathes for cutting, turning and boring blanks which are then forged in vertical hydraulic presses.

At present, mechanized lines for machining round and flat ingots cast by the semicontinuous method are being designed.

The employment of large-capacity smelting furnaces and the casting of large ingots move to the forefront the problem of a timely obtainment of the chemical analysis of the finished ingot or of the melt readied for casting. In recent years, the methods of the chemical and spectral analysis of the cast metals and alloys have been so perfected as to make it possible to obtain more accurate analyses in less time. To obtain satisfactory results it is necessary to employ quantographs which make it possible to pinpoint up to fifteen components and impurities within a short period of time.

#### Manufacture of Flat Rolled Products

This type of rolled products includes strips, sheets, bars and foils, and the methods of their manufacture have also changed considerably.

In the pre-revolutionary times foil (tin and lead) was produced in insignificant amounts and in a primitive manner by faggot rolling in sheet rolling mills. Aluminum foil was not produced in Tsarist times, and so its production had to be started from the ground up. At present, aluminum foil five to 14 microns thick is being manufactured for the food and technical industries. The production of embossed, colored, varnished, and paper-base foil has also been mastered. The quantity of the produced foil should be further increased; the technology of its production has reached a sufficiently high level.

At present, foil is manufactured in high-speed four- and two-high foil-rolling mills with direct-current drive. It is to be expected that in the next few years the volume of output of aluminum foil will expand drastically.

In Tsarist Russia the production of sheets and strips from nonferrous metals existed in a rudimentary stage. The rolling of sheets was carried out on low-speed two-high rolling mills; thick sheets were produced by the piecework method, and thin sheets -- by the faggot method. The rolling of strips was carried out on two-high mills with rollers measuring 240-260 millimeters in diameter, shafts 280-300 millimeters long, and at a rolling speed of 18 to 24 meters a minute. The strips were produced in a thick and rather narrow form. Sheets, bars and strips were produced from copper and brass of the L62 and L68 grades.

Bars and strips of grade-L68 brass were rolled from ingots only in cold state upon employing frequent intermediate annealings. It was thought that the brass could not be rolled when in a hot state.

During the years of Soviet power enormous changes had occurred in the technology of the casting and processing of nonferrous metals, and the volume of their output expanded by dozens and hundreds of times. The production of hundreds of new alloys and thousands of new types of rolled products was mastered; the technical indexes of operation (yield of acceptable product, quality, production costs, productivity) had improved incommensurably, and the technology and refinement of production was greatly perfected.

The modern standard process of the production of copper and brass sheets and strips consists in the following: a heated ingot weighing one to three tons (and, in the not too distant future, five to seven tons) is conveyed to a reversible hot-rolling mill with direct-current drive and with a power rating of 1,300 to 2,500 kilowatts, where it is rolled into strips 800-1,000 millimeters wide and 6-11 millimeters thick. The six-millimeters-thick strips are reeled into rolls, cooled, and conveyed to a stream-pickling machine where they are pickled, in unreeled state, in a sulfuric acid solution, carefully washed, dried and again reeled into rolls. The pickled strips proceed on a conveyor toward a four-high three-cage rolling mill measuring 375/1,000 x 1,000 millimeters, for rolling from six down to three millimeters at the rate of up to 180 meters a minute; after annealing the strip rolls are conveyed back to that mill or to another rolling-mill line for rolling down to the thickness of one millimeter. After their edge is sheared off, the annealed strip rolls proceed toward reversible four-high 250/750x850-1,200 millimeter rolling mills for rolling down to a thickness of 0.5-0.4 millimeters at the speed of up to 240 meters a minute (to be increased to 420 meters a minute in the immediate future); farther on, the



strip rolls, after being annealed, pickled and longitudinally cut, proceed to reversible four-high 160/500x450 millimeter rolling mills for rolling down to a thickness of 0.2-0.15 millimeters; with the rolling rate amounting at present to 300 meters a minute. Still thinner strips are rolled subsequently on twelve-high roll stands with working rollers having a diameter of 38 millimeters and with a rolling rate of up to 300 meters a minute.

To produce sheets, strip rolls of the necessary thickness are removed from the rolling mills, annealed, pickled in roll-straightening machines, and cut into pieces of a given size on special cutting lines consisting of interlocked disk and guillotine shears and rollgangs.

In the immediate future the technology of the production of sheets and strips will apparently become still more simplified. Hot rolling of sheets 1,000-1,200 millimeters wide and 1-3 millimeters thick will be carried out in a planetary rolling mill with 20 to 22 working rollers (diameter: 180-200 millimeters), from an ingot weighing five and more tons.

The subsequent rolling of strips to thinner sizes will be conducted in twenty- and twelve-high rolling mills.

Hot-rolled bars, 11 millimeters thick, destined for the production of high-grade strips and sheets to which special requirements as to purity of surface are posed, are milled from both sides on milling assemblies and thereupon rolled down to a thickness of two millimeters. Their subsequent processing unfolds according to the same scheme as above.

It should be noted that, at present, individual units of certain rolling mills have been automated, and hot rolling proceeds without human attendance: the clamping device in four-high rolling mills of the 250 and 150-160 millimeter type is automatically turned on and off according to the readings of a "letuchyy" micrometer, so as to obtain strips of pre-set thickness and tolerance limits. Moreover, the mills are rigged out with dynamometers indicating the pressure on the rollers during every passage of strip.

In the immediate future it will be necessary to carry out the over-all automation of the entire rolling cycle and to introduce such automation in all present-day rolling mills and auxiliary operation lines.

#### The Manufacture of Pipe, Rods and Sections

Prior to the Revolution the production of sections from nonferrous metals and alloys was virtually non-existent.

A minute amount of medium- and small-size pipe was manufactured from plate skelp rolled in a Mannesmann mill, upon being repeatedly drawn in continuous mills and subjected to frequent intermediate annealings. Large-bore pipe was not manufactured owing to lack of equipment.

Rods of nonferrous metals were manufactured in two hydraulic presses of an archaic design, with capacities of 700 and 1,000 tons respectively, and with 220-atmosphere pressure.

The manufacture of pipe, rods and sections started to develop after the installation of 3,500-, 1,500- and 1,000-ton horizontal hydraulic presses and 300- and 600-ton vertical presses in the Leningrad Plant "Krasny Vyborzhets," and in other plants.

At present, the technology of producing rods by drawing press-forged blanks of considerable length in coils on drums, has found widespread acceptance. This has supplanted the drawing of rods piecewise in continuous mills. Modern tube rolling mills have been installed for the production of tubes from high-strength alloys and tubes with profiled cross sections. In addition, mechanized drawing mills are being installed for the simultaneous drawing of several (up to three) tubes, and the drawing of copper tubes on drawing drums with a floating straightener is being mastered.

The introduction and widespread application of hard-alloy drawing and pressing tools has been greatly conducive to the advancement of the technology of the production of rods and, particularly, of tubes.

Due recognition has been given to the high-frequency heating of ingots prior to forging them in 600-ton vertical presses, which is particularly important in obtaining cupronickel capacitor tubes of good quality and nickel blanks for the subsequent manufacture of tubes with diameters of four to 0.8 millimeters used in the production of radio vacuum tubes and radio equipment.

The further development of tube production should proceed upon taking into account their specialization, according to alloy and size, so as to make possible the designing of high-productivity assemblies and to organize the continuous-flow production of tubes of definite sizes from definite alloys. To increase labor productivity, it is necessary to speed up the work on the modernization and automation of horizontal hydraulic presses in the nonferrous metals processing plants.

## New Types of Production

The ceaseless development of various branches of the national economy requires the mastering of ever newer types of rolled products.

The dynamic mushrooming of the aviation industry has led to the expansion of the aluminum industry, whose twenty-fifth anniversary was recently commemorated in our country, and to the development of the production of rolled aluminum and magnesium products. These types of rolled products were first mastered in the following plants: Kol'chugino, "Krasnyy Vyborzhets," and imeni Voroshilov. Subsequently, this production has grown considerably and was transferred to other nonferrous metals processing plants.

The years of Soviet power have witnessed the mastering of the manufacture of such new materials as bimetals -- steel-tombac, iron-Armco, aluminum-magnesium-antimonous alloy, various grades of thermo-bimetals, aluminized iron, aluminized nickel, powders and poudres of nonferrous metals and alloys, and the like.

In summing up the results of the forty-year activity of nonferrous metals processing plants, it can be stated that a great deal of work has been done in this field too. Dozens of new, modern plants have been built and the old ones have been modernized. Year after year the plants are perfecting their technology and renovating their equipment. The nonferrous metals processing industry has reared numerous cadres of outstanding experts and workers.

In the next few years the pace of advances in technology and the growth in the volume of the production of rolled nonferrous metal products should be doubled and tripled.

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[Inset on p 85]

### The Kol'chugino Plant

In the year 1870 a copper-brass plant was founded on a bank of the Peksha River in Vladimirskaya Oblast. In the years of Soviet power it became nearly completely modernized and converted into the country's largest Kol'chugino Nonferrous Rolled Products Plant imeni Sergo Ordzhonikidze.

During the Great War for the Homeland a major part of the plant's equipment was evacuated



to the East. On the basis of that equipment, new nonferrous rolled plants were established in the Urals and Kazakhstan.

During the postwar period the Kol'chugino Plant was completely reconstructed and equipped with the most up-to-date furnaces and rolling mills. It operates broadly on modern technology and it is introducing automation. During the Sixth Five-Year Plan this plant had signally expanded its output of nonferrous castings and rolled products for the Nation's economy.

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[Inset on p 877]

### Secondary Nonferrous Metals

The very first smelting of secondary copper from the scraps and wastes of nonferrous metals was organized in the USSR in 1922 at the Moscow Copper Electrolysis Plant, and of secondary aluminum, in 1928 at the Moscow Recovery Plant (now Secondary Aluminum Plant).

The preparation of raw material used to be done by hand, and the smelting, by the cottage-industry method in small cast-iron vats having a productivity of 2.7 tons daily.

At present nine up-to-date secondary nonferrous metals plants are operating in the Soviet Union.

The plants of secondary nonferrous metallurgy are producing high-grade alloys, including over 20 grades of aluminum alloys, over 10 grades of bronze alloys and nine grades of brass alloys, which reduces considerably the demand for primary nonferrous metals.

## 2. From the Past and Present of Kounrad

/This is a translation of an article written by V. Tyuryutikov in Byulleten' Tsvetnoy Metallurgii, No 19/20 (96-97), 1957, pages 29-30./

The discovery and development of the Kounrad Copper Deposit and the construction of the Balkhash Copper Smelting Plant exerted a major influence on the development of Kazakhstan's industry.

The construction of that giant of the Soviet non-ferrous metallurgy, the Balkhash Copper Smelting Plant, whose raw material base is the ores of the Kounrad Deposit, was viewed by the Party and State as a project of an exceptionally great importance.

A difficult task fell to the lot of the first discoverers and geologists, whose persistent toil had provided access to the incalculable riches lying in the bowels of the Earth and had placed them in the service of the Soviet man.

The geologist Mikhail Petrovich Rusakov, now active member of the Academy of Sciences Kazakh SSR, is rightly considered as the pioneer in unlocking the Kounrad Deposit. In 1929 the first team of prospecting geologists was set up under his guidance, and 25 June 1929 marked the beginning of the drilling of the first borehole, thereby becoming known as the first day of the development of the largest copper deposit in the USSR.

Towards 1934 the Balkhash Pilot Concentrator Plant was constructed, and soon it began to process the Kounrad ores. In 1938 the Balkhash Copper Smelting Plant produced its first tons of blister copper. Throughout the period of existence of the Kounrad Mine over 220 million tons of bulk material, including over 96 million tons of ore, were extracted.

Such an intensive rise in the enterprise's output capacity has been made possible by the judicious selection of methods of working the deposit, use of new high-capacity technological equipment, continuous improvements in the organization of labor, increase in the skills of the collective of workers, engineers and technicians, and rise in labor productivity.

At present the mine's equipment includes excavators with a bucket holding three cubic meters, normal-gauge 94-ton electric locomotives, and Soviet-produced percussive-rope drilling rigs. The new technological equipment plays a major role in the work of miners. Starting in 1956 the first models of Soviet-produced excavators with a bucket

holding six cubic meters began to be used in the mine.

In the year 1956 one such excavator had handled over a million cubic meters of bulk rock, and its productivity per cubic meter of bucket capacity amounted to approximately 174,000 cubic meters of bulk rock. New and more powerful BS-1 drilling machines and new transport equipment -- 150-ton electric locomotives and 90-ton dumpcars -- are being acquired. The collective of workers, engineers and technicians is struggling with great enthusiasm for a pre-term fulfillment of the State plan and for a successful mastering of the new technology.

According to a revised project, in the next four years the enterprise's output capacity should be more than doubled compared with its actual capacity in 1956, and labor productivity should (correspondingly) amount to 32 cubic meters per man-shift instead of 17.3 cubic meters.

It is necessary to equip the mine more broadly with six-cubic-meter excavators, and 90-ton dumpcars; a "STsB" system /Communications, centralization, block/ should be installed; and the dwelling area will be expanded by another 60,000 square meters, on providing the workers' settlement with greenery and various communal amenities.

The collective of the Kounrad Mine has, during its many years of work, trained numerous highly skilled cadres. A deserved high reputation among the miners is enjoyed by the Senior Excavator Operator I. Guryayev, Excavator Operator Brigade Leader M. Demchenko, Innovator and Operator of the Six-Cubic-Meter Excavator Brigade Leader I. Vagner, Senior Drilling Machine Operator M. Syzdykov, Locomotive Driver and Deputy of the Oblast Council of Workers' Deputies A. Kozhayev, Leader of Blasters' Brigade B. Akimbekov, Leaders of Road Brigades A. Popryadukha and M. Barlibayev, Assembler B. Arsamuznev, Leader of Locomotive Repair Brigade A. Shivetin, and many others.

### 3. The Development of Copper and Nickel Metallurgy in the USSR Over a Forty-Year Period

[This is a translation of an article written by V. I. Smirnov in Byulleten' Tsvetnoy Metallurgii, No 19/20 (96-97), 1957, pages 40-45.]

The pre-Revolutionary Russia had a feebly developed copper industry and it did not extract any nickel at all.

During the 40 years of the Soviet Union the smelting of copper was greatly increased; as for nickel, which has been smelted in our country since 1935, the Soviet Union is among the world's top nickel producers.

With the copper and nickel industry as the basis we have established a cobalt industry, as well as the production of selenium and tellurium; the by-product recovery of noble metals and metals of the platinum group has increased drastically.

A major achievement of the Soviet Union in the field of the metallurgy of copper and nickel has been not only the quantitative rise in the smelting of these metals but also the qualitative changes in the methods of their production.

Prior to the October Revolution the ores extracted and transmitted for metallurgical treatment were mostly rich ores or ores with a medium content of metals. The principal method of treatment of these ores was the method of the smelting of charge into matte. In the Urals, where ores of a pyritic nature were extracted, pyritic or semi-pyritic smelting was applied on a fairly large scale since the beginning of this century. This was also the case in the Caucasian plants.

In the plants of the Urals and Caucasus the smelting of rich ores and plant dusts in reverberatory furnaces used to be applied on a limited scale as a subsidiary method.

In the Soviet Union sulfidic ores are basically processed by the method of flotational concentration, which makes it possible to utilize comprehensively their material composition. The flotation justifies economically the processing of low-grade ores and increases the total industrially exploitable reserves of the explored deposits.

The processing of copper concentrates has become widely based on their smelting in reverberatory furnaces after their prior roasting or drying.

Original methods of metallurgical processing have been applied in the nickel plants of the Soviet Union. Thus, oxidized ores are processed by the method of sintering and subsequent shaft-furnace smelting of the sinter together with

sulfidizing admixtures into matte. The sulfidic ores containing both nickel and copper are smelted not only in shaft furnaces but also in large electric arc furnaces. New methods of recovering metals from nickel and copper-nickel nis mattes have been developed and are being applied: processes of roasting in multiple-hearth and tubular mechanical furnaces, electric smelting of nickelous oxide into metallic nickel, flotational concentration of nis mattes, etc.

The following periods may be distinguished in the development of copper and nickel metallurgy in the Soviet Union during the last 40 years: reconstruction, first five-year plans, and postwar.

During World War I, in connection with the mobilization of workers and the difficulties in supplying plants with coke and other materials, Russia's copper industry started to decline and, during the subsequent years of the Civil War, it came to a complete standstill. Between 1918 and 1921 absolutely no smelting of copper was conducted on our country's territory.

The problem of the electrification of the country, brought to the forefront by V. I. Lenin in his illustrious GOELRO Plan /State Commission for the Electrification of Russia/ had naturally drawn attention to the problem of reconstructing and developing the copper industry.

The first copper in the Soviet Union was smelted in the Urals at the Kalatinsk (now Kirovgrad) Plant, which was reconstructed and activated in May 1922. This was followed by the activation of the Nizhne-Kyshtym Electrolysis Plant and the Allaverdskiy, Tanalyko-Baymakskiy and Pyshma-Klyuchevskiy copper smelting plants. In 1925 the largest copper-smelting plant of pre-Revolutionary Russia in Karabash was reconstructed and reopened. By the years 1927-1928 the reconstruction of the copper industry had been fundamentally completed: the smelting of copper was raised to the 1914 level. In 1928 the Karsakpay Plant was opened.

Inasmuch as in the old copper-smelting plants shaft-furnace smelting was the principal method of treating copper ores, it was this process that had attracted the greatest attention of metallurgists in the Nineteen Twenties. In the Ural plants the process of the pyritic smelting of copper ores was considerably perfected: smelting upon replacing a major part of coke by anthracite was mastered; the "Ural method" of regulating the smelting by charging-in heating burdens, which makes it possible to conduct the process for a long time without any special disturbances and complications, was developed and applied; and a considerable intensification of smelting had been achieved. Interesting studies

were carried out to clarify the effect of fluxes on the composition and yield of the products of pyrite smelting (Karbash and Kalatinsk plants), to clarify the content and form of oxygen in copper mattes (Professor V. Ya. Mostovich, and to determine the optimal mode of blowing in shaft furnaces. The Pyshma-Klyuchevski Plant in 1925 had developed and introduced into practice a method of comprehensive processing of copper-zinc scrap with the recovery of copper and zinc, in converters. The Nizhne-Kyshtym Electrolysis Plant had mastered the operation of processing the slimes of copper electrolysis into dore metal (until the Revolution these slimes used to be exported for processing abroad), and had developed a method of by-product recovery of selenium and tellurium from the slimes. The new Karsakpay Copper Smelting Plant had mastered in 1928-1929 the smelting of copper concentrates in reverberatory furnaces fired with coaldust.

The second period in the development of the copper industry of the Soviet Union, i. e., the period of five-year plans, was characterized by the construction of a number of nonferrous-industry enterprises (ore mines, concentrators and plants) and the modernization and expansion of old enterprises. The enterprises then designed and built were the Krasnoural'sk Copper Smelting Plant, Pyshma Copper Electrolysis Plant, Blyava Copper-Sulfur Plant, Sredneural'sk and Balkhash copper smelting plants, and also a number of large concentrator plants and ore mines.

To design the new enterprises of the metallurgical industry, the Gipromet State Institute for the Design and Planning of Metallurgical Plants was organized in Leningrad as early as in the mid-twenties, together with a branch in Sverdlovsk. Later on a special institute for the design and planning of nonferrous metallurgy enterprises -- the Giprotsvetmet, and in the Urals -- the Uralgiprotsvetmet, was separated from the Gipromet and given independent status.

The design and planning of the new nonferrous metallurgy enterprises was carried out by Soviet experts without foreign assistance; it was only in the initial stage of activities of these institutes -- in isolated instances -- that foreign consultants were enlisted for solving certain special problems pertaining chiefly to the field of concentration.

As noted before, the new enterprises of the copper industry were designed and built according to new technological schemes. Except for the Mednogorsk Copper-Sulfur Plant, where the processing of the local cupriferous pyritic ores was based on an improved method of pyritic smelting involving the recovery of molecular sulfur from gases, all the other copper-smelting enterprises employed the method of the



flotational concentration of ores with the smelting of copper concentrates in reverberatory furnaces.

Thus, the reverberatory smelting of previously roasted copper concentrates was carried out on a large industrial scale at the Krasnoural'sk Copper Smelting Plant, which was activated by the end of 1931. Two old plants (in Kirovgrad and Karabash) were being modernized and expanded at the same time: in each of these plants reverberatory furnaces were being built for smelting the concentrates from the local concentrator plants.

The end of the Nineteen Thirties was marked by the nearly simultaneous completion of the construction of the first batteries of the Sredneural'sk and Balkhash plants, which had organized the smelting in reverberatory furnaces of concentrates previously dried in tubular furnaces.

All the copper-smelting plants had installed large horizontal converters with basic lining for processing mattes into blister copper. Straight-line pouring machines for pouring molten copper were installed and mastered in the plants.

The Pyshma Copper Electrolysis Plant was built and activated at the beginning of the thirties. This was the first large and completely modern refining plant in our country. It was provided with large mazut-burning refining furnaces and equipped with high-capacity pouring machines and heat-recovery boilers. To avert the accumulation of copper and impurities in the solutions, a part of the electrolyte there is transferred to the copper sulfate shop, which produces copper and nickel sulfates. The plant's slime shop processes slimes into dore metal and carries out the by-product recovery of selenium and tellurium from the slimes.

The Nineteen Thirties were also marked by the conduct of extensive design, research and construction activities in the field of the nickel industry.

As early as in 1925--1927 the First and Second Conferences on Nonferrous Metallurgy had adopted resolutions for erecting in the Urals the first nickel plant for processing the oxidized nickel ores of Ufaleyskiy Rayon. The design of that plant was initially in the hands of the Ural Branch of the Giprometz, and was later completed by the Uralgiprotsvetmet. The studies to determine the technology of processing the oxidized nickel ores were initially conducted at the Sverdlovsk Affinage Plant (by Professor N. N. Baraboshchkin and Engineer A. A. Mironov), and later in the early Nineteen Thirties, on a larger scale, at the Polevskiy Copper Smelting Plant. The construction of the Ufaley Nickel Plant was completed in 1933; by the end of that year it was set in operation.



During the period of construction of the Ufaley Plant extensive deposits of oxidized nickel ores were discovered in the Southern Urals and deposits of copper-nickel sulfidic ores-- in the Kola Peninsula. This was accompanied by supplementary geological exploration of the previously known Noril'sk copper-nickel deposits, which yielded extremely favorable results. The State decided to erect large nickel combines on these deposits. In this connection, a new design institute, the Soyuznikel'olovoprojekt /All-Union Institute for the Design and Planning of Nickel and Tin Industry Establishments/, was organized in 1935 in Leningrad.

In 1935-1939 that Institute carried out the design of huge nickel-industry enterprises: the Yuzhnoural'sk Nickel Combine, and the Monchegorsk and Noril'sk copper-nickel combines, as well as enterprises of the tin industry.

The first batteries of these new plants, which were activated nearly simultaneously during the 1938-1939 period, had increased steeply the smelting of nickel.

As distinguished from the Ufaley Plant, which subjected the oxidized ores to briquetting, the Uzhnoural'sk Plant had introduced the sintering of ores and, for the purpose of roasting nis matte, it had installed multiple-hearth and tubular mechanical furnaces instead of reverberatory furnaces with manual rabbling.

The technology of the processing of the copper-nickel sulfide ores of Kola Peninsula was investigated in the laboratories of Leningrad Mining Institute (Professor N. P. Aseyev, K. F. Beloglazov, N. S. Greyver, and others) and Electrical Engineering Institute (Professor Maksimenko). Shaft and electric furnaces were installed as smelting equipment in plants. The copper-nickel mattes from the shaft and electric furnaces are blown through in converters into copper-nickel nis mattes. The further processing of these nis mattes was planned according to the method of separatory smelting. The lower product ("bottom") in separatory smelting is subjected to two-stage roasting, with the roasted charge being smelted in electric furnaces into anodes which are then conveyed for electrolytic refining.

At the Noril'sk Combine sulfide ores and concentrates are charged in sintered form into shaft furnaces for smelting. The copper-nickel nis mattes initially were processed according to the combined hydroelectrometallurgical method; after the war the selective flotation of the nis mattes, yielding nickel and copper concentrates, was mastered.

The nickel plants organized the recovery of cobalt from converter slags and other intermediates of nickel production. The first metallic cobalt in the USSR was obtained

at the Ufaley Plant in 1937, from iron-cobalt cakes obtained while refining the solutions for the production of nickel sulfate. The cobalt recovery scheme was worked out by the Gintsvetmet /State Institute of Nonferrous Metals/ (Professor Pletenev) and by the workers of the Ufaleyskiy Plant. In 1938 the same plant had also organized the recovery of cobalt from the converter slags of nickel production. These converter slags were subjected to reducing-sulfating smelting into matte in a small shaft furnace. Various methods were employed to process the nickel-cobalt matte; the ultimately adopted method was that of the oxidizing-chlorinating roasting of the matte, with subsequent leaching of the roasted charge. The leaching solution was subjected to subsequent fractional rectification so as to remove impurities, whereupon it was used to precipitate cobalt according to the hypochloritic scheme.

At the Yuzhnoural'sk Nickel Combine the scheme developed at the Ufaley was considerably modified. That combine introduced the method of blowing through molten nickel-cobalt mattes in a converter so as to transform the composition of the enriched mass to that of the anode melt. The melt was used to cast anodes which are then conveyed for electrolytic dissolution in baths, in a solution of sodium chloride. Then nickel, cobalt and other metals pass into the pulp in the form of hydroxides. The filtered cake of the hydroxides is dissolved in acid and the resulting solution is processed according to the conventional hypochloritic scheme.

At the "Severonikel" Plant in Monchegorsk converter slags are smelted in electric furnaces into a melt which is subjected to electrolytic dissolution in sulfuric-acid solutions, so as to isolate copper within the cathode residue.

In all nickel plants cobalt is recovered from the solution in the form of a hydroxide which is subjected to drying and to calcining in electric furnaces. A method for the reduction smelting of the higher and lower oxides of cobalt into metallic cobalt has been developed and is being applied in Gramolin-Shteynberg's electric furnace.

In the processing of oxidized nickel ores the electric smelting of nickelous oxide is the final stage of production. The obtained metal is usually subjected to granulation and shipped to users in the granular form.

Nickel is obtained from sulfide ores in the form of electrolytic metal. During the electrolysis of anode nickel, metals of the platinum group are extracted into slime while cobalt is extracted into the cake obtained on filtering the solutions.

During the Great War for the Homeland, in connection

with the temporary evacuation of the "Severonikel'" Plant and the shortage of electrical energy in the Ural plants, the development of the production of copper and nickel in our country had been somewhat slowed down. However, the wartime years too were marked by well-known achievements in the application of new processes and expansion of the recovery of the metal co-components of copper and nickel ores.

Thus, at the beginning of the war, the problem of the selective flotation of the ores of the Pyshma Deposit in the Urals was resolved upon isolating cobalt within a special pyrite concentrate. The process of the oxidizing-sulfating roasting of pyrite concentrates with subsequent leaching of the roasted charge and extraction of cobalt in the form of a hydroxide from the solutions was developed and introduced.

The Balkhash Plant had introduced at the beginning of the war, on an industrial scale, the re-flotation of the Kounrad copper concentrates with the isolation of molybdenum into substandard molybdenum concentrate. That era had also been marked by the mastery of the flotation of the molybdenum ores of Eastern Kounrad, which yielded quality-grade molybdenum concentrates. A method of retreating the substandard concentrates into calcium molybdate had been developed.

The Yuzhnoural'sk Nickel Combine had considerably intensified its shaft-furnace smelting of sintered nickel ores by lowering somewhat the level of furnace charging and increasing the air delivery. Other copper-smelting and nickel plants were conducting experiments to replace a part of the coke used in shaft-furnace smelting by the cheaper and less scarce blast-furnace coal. The nickel plants had increased the recovery of cobalt from the converter slags of their nickel production.

In 1944-1945 the "Severonikel'" and "Pechenganikel'" plants were successfully reconstructed and normalcy was re-introduced into the operations of the copper-smelting plants.

The postwar period has been characterized by a considerable intensification of the processes of the reverberatory smelting of roasted concentrates at the Krasnoural'sk Plant and dried concentrates at the Balkhash and Sredneural'sk copper-smelting plants. A major role in the process of reverberatory smelting was played by design modifications of the fuel burners (KMZ, SUMZ) Krasnoural'sk Copper Smelting Plant and Sredneural'sk Copper Smelting Plant, slight heating of the air (MZ), and modifications of the actual design of furnaces.

The Kirovgrad Plant conducted studies to recover zinc from nattes and concentrates into distillates during the

bessemerizing process, which studies yielded positive results and served as the basis for constructing bag filters and a coaldust installation at that plant. The method of the so-called pyro-selection of zinc has at present been introduced into the plant's everyday practice.

In the postwar era the Gintsvetmet had been investigating a new method of recovering selenium from the slimes of copper electrolysis by sintering the slimes with soda and by subsequent leaching of the sinter. This method was introduced at the Pyshma Copper Electrolysis Plant where it made possible an increased recovery of selenium.

During the postwar years new reverberatory furnaces for smelting copper concentrates were built at the Noril'sk, Balkhash and Sredneural'sk plants. The industrial base of the copper electrolysis industry was augmented by the expansion of the Pyshma Plant and the construction of anode and electrolysis shops at the Balkhash Plant. As a result of the intensification of the process of shaft-furnace and electric smelting, the production of the nickel plants had increased greatly. New processes were developed and introduced for recovering cobalt from the wastes of nickel production (the process of the retreatment of molten converter slags at the YUNK /Yuzhnoural'sk Nickel Combine/, and others), so as to increase the recovery of that metal.

Side by side with all the achievements in the field of their production our copper-smelting and nickel plants still display many shortcomings, the principal ones being unsatisfactory preparation of materials for smelting, inefficient dust collection, and insufficiently comprehensive processing of materials.

Materials with a considerable percentage of fines are transmitted for shaft-furnace smelting, and this restricts furnace productivity and increases furnace dust escape and irrecoverable losses of metals. The improvement of the preparation of materials for shaft-furnace smelting through a careful screening of ores and sintering of fine materials, and also through an improvement in the quality of the sinter itself, will make it possible to upgrade appreciably all the indexes of shaft-furnace smelting.

In certain plants the increase in furnace productivity is still being hampered because of the insufficient power of air-blast devices, although the use of heated air and oxygen-enriched air provides a possibility for a considerable intensification of smelting.

Doubtless, dust collection is the Achilles' heel of our copper-smelting and nickel enterprises. So far, thorough purification of plant gases has not yet been introduced in

such giant enterprises as the Balkhash and Sredneuralsk copper smelting plants, the Yuzhneuralsk Nickel Combine and the Noril'sk Copper-Nickel Plant.

Valuable components of ores and concentrates are not being completely recovered. The plants' sulfur dioxide gases are used for producing sulfuric acid only in certain plants -- and, moreover, very incompletely. As a result of the fine mutual interpenetration of the sulfides of diverse nonferrous metals in copper ores, during the concentration of these ores, no success is achieved in a complete separation of sulfides according to the concentrates of various metals, so that copper concentrates with a high content of zinc and an appreciable content of lead sometimes are processed. Zinc and lead can be extracted from copper concentrates into distillates during the processing of these concentrates in the copper-smelting plants by applying various distilling processes (the fuming of molten zincous slags, electrothermal processes of the retreatment of materials, pyro-selection in converters, etc.).

The Directives of the 20th Congress of the CPSU for the Sixth Five-Year Plan outlined the principal tasks of the development of the Nation's economy as a whole and according to individual branches. These Directives stipulated a signal increase in the output of nonferrous metal during that five-year period, including a 60-percent increase in the output of copper and nickel compared with the 1955 level. A considerable part of this increase in output was intended to be achieved through a more complete utilization of existing output capacities and the application of new and more productive processes. Therefore, particularly great importance has been attached to the further intensification of metallurgical processes and introduction of new processes increasing the recovery of metal and the comprehensiveness of utilization of the material composition of the processed ores.

In the Directives of the 20th Congress of the CPSU very great importance has been attached to the use of oxygen in both ferrous and nonferrous metallurgy. The plants of nonferrous metallurgy have already conducted the first tests of the use of oxygen-enriched air. Thus, the Yuzhneuralsk Nickel Combine has carried out trials of the enriched-air smelting of sintered nickel ore in a shaft furnace; in 1956 the Balkhash Plant experimented with the smelting of atomized copper concentrates in heated air and in oxygen-enriched air; the Krashneuralsk Plant conducted a regular series of tests of the use of oxygen in the bessemerization of mattes, etc. All the preliminary tests have proved the great effectiveness



of the use of oxygen.

The introduction of oxygen into metallurgical processes on a large industrial scale will become feasible after large oxygen stations are built in the plants. At present such stations are being built at the Balkhash and Irtysk copper smelting plants, the Ust'-Kamenogorsk Lead-Zinc Combine, and certain other enterprises. The YUNK has already constructed a small oxygen station producing 1,000 cubic meters of oxygen per hour.

Of the new high-productivity processes the ones currently attracting the greatest attention of metallurgists are the processes of roasting and smelting in molten or suspended state. Such processes include the roasting of concentrates in a fluidized bed, which has already been introduced in all of our zinc plants, and which has proved its effectiveness in regard to the productivity of furnaces, utilization of the calorific value of concentrates and obtainment of gases with a high content of sulfur dioxide.

Of special interest in the metallurgy of copper and nickel is the combined process of the roasting and smelting of pulverized concentrates in heated air or in oxygen. This type of process includes the so-called cyclone smelting of copper concentrates.

The industrial mastering of the combined process of roasting and smelting of pulverized concentrates in heated or oxygen-enriched air will indubitably increase the productivity of the existing plants and improve the technical-economic indexes of their operations.

To recover zinc and lead from copper concentrates and the products of their processing, many copper-smelting plants of the USSR should employ various distilling processes, particularly the process of the fuming of molten zincous slags and also, if possible, the vacuum processes.

There exist broad prospects for the employment of electrothermal processes. In the metallurgy of copper electric furnaces should find application for smelting cathodes and, in isolated instances, for smelting ores and concentrates.

The improvements in gas purification and dust collection will make it possible to increase the recovery of metals and to organize the obtainment of certain rare metals which had hitherto been irrecoverably lost in gases. The comprehensive retreatment of fine plant dusts and distillates requires the employment of various combined schemes in which hydrometallurgical processes will play a major role.

Of the new processes in the metallurgy of nickel a noteworthy one is the perfected carbonyl process employing

high producer-gas pressures, which will make it possible to obtain high-purity metal and an efficient recovery of non-ferrous and platinum metals.

The further progress of the electrolysis industry requires the introduction into industrial practice of the continuous electro-deposition process in which metal is obtained in the form of a strip being continually removed from the cathode, current density is increased and the purification of solutions is more thorough.

There exist all the necessary objective conditions for the further development of the metallurgy of copper and nickel in the USSR: substantial proven reserves of ores of these metals, a large machine-building industry capable of providing new enterprises with the necessary equipment, the required power base, etc. We have trained numerous cadres of skilled workers and experts. Without any doubt, the copper and nickel industry shall continue to develop in our country, and it shall be assured of a leading position among the world's producers.

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[Inset on p 42]

#### Greater Dzhezkazgan

One hundred and ten years ago, on 10 November 1847, the first steps to extract copper ore were taken in Dzhezkazgan.

In 1906 the Dzhezkazgan Copper Deposit was leased out to the English, who had established a corporation, "Atbassar Copper Company, Limited," for its exploitation.

There commenced the predatory selective extraction of only the richest ores from the Uspenskoye Deposit west of Dzhezkazgan. Plans existed for a similarly predatory working of Dzhezkazgan itself, but after the October Revolution the "concessionaires" were banished.

The new period in the development of Dzhezkazgan began on 10 June 1925. On that day the Soviet of Labor and Defense adopted the decision, for completing the construction of the Karsakpay enterprises and activating them.

On 7 November 1928 the first Soviet copper was produced at the Karsakpay Plant.

Soviet geologists uncovered the bountiful



resources of the Dzhezkazgan Deposit in their entire diversity: new reserves of copper, and also of lead, iron, manganese, precious metals, black coal, refractory clays, talcum stone, limestone.

The present-day Dzhezkazgan contains a very considerable part of the explored reserves of copper in the Soviet Union; in its resources it surpasses the richest copper deposits of Chugucamata in South America.

During the postwar five-year periods, carrying out the decisions of the Party and State to create the Greater Dzhezkazgan, the workers of non-ferrous metallurgy built many large underground and open-strip mines, created a highly developed mining system, and built a concentrator plant, a copper smelting plant, and auxiliary shops and facilities. Greater Dzhezkazgan, the country's new huge copper-industry center, is being built and expanded.

#### 4. Economic Appraisal of Ore Extraction for Various Methods of Mining

[This is a translation of an article written by Ye. I. Dobroserdov in Byulleten' Tsvetnoy Metallurgii, No 18 (95), 1957, pages 29-34.]

The costs of extracting one ton of ore (according to 1955 figures) in certain mining enterprises of nonferrous metallurgy have the structure shown in Table 1.

Table 1

Structure of (Shop) Ore Extraction Costs, in percent

Ore Mine	Expenditures				Mine Development Work	Overhead*
	Wages	Power	Materials	Amortization		
Belousovka	39.09	5.41	9.35	5.22	5.51	35.42
Berezovskiy	38.85	6.86	7.25	6.93	5.4	34.73
Zyryanovsk	35.35	5.31	6.51	9.27	5.24	38.32
Leninogorsk	33.83	6.02	8.30	2.18	12.83	36.84
Sokol'nyy	39.43	4.02	10.94	2.8	4.5	38.31
Bystrushinskiy	32.85	4.38	8.63	7.02	7.03	40.09

\*Running repairs, shop and miscellaneous expenses.

As can be seen from Table 1, the decisive factor in the extraction costs per ton of ore is constituted by wages and overhead expenses, which together account for 70 to 78 percent of the total shop costs.

The postwar period has been marked by a rise in the skills of workers consolidation of the permanent cadres, decrease in the "fluidity" [turnover of labor force], and the beginning of the introduction of technically justified output quotas, as well as the materialization of other organizational-technical measures.

As a result, labor productivity has risen, the absolute value of wages paid per extracted ton has decreased and, therefore, the extraction costs per ton of ore have declined (Table 2).

Table 2

Rise in Labor Productivity and Decrease in Ore Extraction  
Costs in 1955 Compared with 1950, in percent

Ore Mine	Rise in the Productivity of Workers		Decrease in Wages Paid Per Ton of Extracted Ore	Decrease in Ore Extraction Costs
	In Stopes	For the Mine as a Whole		
Belousovka	+ 85.0	+ 69.5	-32.9	-26.2
Berezovskiy	+ 61.2	+ 44.8	-27.3	-22.8
Zyryanovsk	+ 32.3	+ 51.6	-32.5	-33.2
Leninogorsk	+ 32.7	+ 43.5	-30.0	- 6.6
Sokol'nyy	+184.0	+150.0	-47.34	-41.8
Bystrushinskiy*			-46.0	-41.0

\*In 1955 in percent of 1952

However, despite the inevitable decrease in the value of wages paid per ton of extracted ore, the percentile share of wages in the total extraction costs -- although in general it declined in the last few years -- remains subject to fluctuations, as can be seen from the data cited in Table 3.

Table 3

Dynamics of the Percentile Share of Wages in the Total  
Extraction Costs per Ton of Ore in 1950-1955

Ore Mine	Year					
	1950	1951	1952	1953	1954	1955
Belousovka	43.0	42.8	41.4	37.9	40.6	39.09
Berezovskiy	41.25	40.4	44.57	38.07	35.24	38.85
Zyryanovsk	35.14	--	--	46.3	39.25	35.35
Leninogorsk	45.15	44.8	42.1	35.9	35.7	33.83
Sokol'nyy	43.85	42.8	42.7	33.9	41.84	39.43
Bystrushinskiy	--	--	40.0	25.5	32.0	32.85

The present article examines the changes in the ore extraction costs and the formation of the structure of these costs in accordance with labor productivity of the group of

stoze workers according to various systems under the conditions of a fixed and a rising output, respectively, of the mining enterprise; and also, it examines the effect of the gradual depletion of ore on the costs of its extraction.

#### Changes in the Ore Extraction Costs According to the Mining System in a Mine With a Fixed Output

The extraction costs per ton of ore in one of the mines of nonferrous metallurgy amounted to (according to figures for February 1956) 86 rubles 16 kopeckas; the structure of these costs for that period is cited in Table 4.

Table 4

#### Structure of Extraction Costs for February 1956

Item of Expenditure	Sum Total	percent
	rubles--kopeckas	
Auxiliary Materials	8-37	9.69
Wages plus Bonuses	32-05	37.09
in which: for Stope Workers	16-00	18.60
Electrical Energy and Compressed Air	3-80	4.40
Mine Development Costs	5-19	6.00
Amortization	8-95	10.36
Overhead Expenses	28-05	32.46
Total	86-41	100.0
Reimbursement of Costs of By-Product Extraction of Ore	0-25	
Shop Costs	86-16	

The mine applied various systems of mining: by horizontal layers, with flushing; by sublevel drifts, with and without flushing of chambers; and by forced block caving. Approximately 60 percent of the ore was extracted by the more productive mining systems.

To determine the extraction costs per ton of ore separately for each mining system, appropriate calculations were executed on the basis of the following conditions:

(1) The cost of forest materials is determined according to the volume of timbering operations for each mining system and according to the list prices of these materials;

(2) The basic wage is computed according to quotas and official wage rates in the mine, in accordance with the volume and organization of operations for each mining system;

(3) The mine-development costs are determined according to the actual cost per cubic meter of bulk material extracted from entries and according to the extent of development required by each mining system;

(4) For the sake of simplicity, the expenditures on auxiliary materials (except for the forest materials), electrical energy, compressed air, amortization, and overhead, are nominally assumed to be on the fixed level of the actual February 1956 expenditures.

On adopting the above-expounded method of calculating the extraction costs per ton of ore, we obtain the following indexes for the individual mining systems applied at the mine (Table 5).

Table 5

Extraction Costs Per Ton of Ore According to Various Mining Systems

Expenditure Item	Horizontal Layers, With Flushing		Sublevel Drifts, With Chamber Flushing		Sublevel Drifts Without Chamber Flushing		Forced Block Caving	
	Sum Total rub-les-kop-eykas	%	Sum Total rub-les-kop-eykas	%	Sum Total rub-les-kop-eykas	%	Sum Total rub-les-kop-eykas	%
Auxiliary Materials	8-02	10.17	7-32	9.54	4-97	7.68	4-96	7.95
Wages and Bonuses*	24-77	31.40	22-70	29.59	13-05	20.17	12-94	20.74
in which: for Stope Workers	10-46	13.49	8-94	11.45	2-75	4.25	2-67	4.28
Electrical Energy and Compressed Air	3-80	4.82	3-80	4.95	3-80	5.87	3-80	6.09
Mine-Development Costs	5-30	6.72	5-90	7.69	5-90	9.12	3-70	5.93
Amortization	8-95	11.34	8-95	11.66	8-95	13.83	8-95	14.34
Overhead Expenses	28-05	35.55	28-05	36.57	28-05	43.33	28-05	44.95
Total	78-89	100	76-72	100	64-72	100	62-40	100
Reimbursement of Costs of By-Product Extraction of Ore	0-31	0.39	0-57	0.75	0-38	0.59	0-16	0.25
Shop Costs	78-58		76-15		64-35		62-14	

\*Excluding wages in the complex items

Table 6

Per-Ton Costs of Extraction by Various Mining Systems In  
Percent of Per-Ton Costs of Extraction by the System of  
Horizontal Layers With Flushing

Item of Expenditure	Mining System			
	Horizontal Layers With Flushing	Sublevel	Drifts	Forced Block Caving
		With Chamber Flushing	Without Chamber Flushing	
Auxiliary Materials	100.0	91.3	62.0	61.8
Wages Plus Bonuses*	100.0	91.7	52.7	52.3
in which: for Stope Workers	100.0	85.5	26.3	25.5
Electrical Energy and Compressed Air	100.0	100.0	100.0	100.0
Mine-Development Costs	100.0	111.3	111.3	69.8
Amortization	100.0	100.0	100.0	100.0
Overhead Expenses	100.0	100.0	100.0	100.0
Total	100.0	97.3	82.0	79.0

\*Exclusive of wages in the complex items

It follows from Table 6 that under the conditions of a fixed volume of ore extraction conducted by such productive mining systems as those of sublevel drifts without chamber flushing and of forced block caving, the expenditures on wages decline considerably (by 48 percent); especially for the group of stope workers (to one fourth). Nevertheless, the extraction costs per ton of ore for these systems decline altogether by only 18 to 20 percent compared with the extraction costs for the system of horizontal layers with flushing. This happens because of the much greater percentile share of the wages for auxiliary workers and of overhead expenses, whose absolute value does not change upon the introduction of the new mining systems (under the conditions of a fixed productivity of the mine).

It is also to be noted that the gap between the average actual extraction costs for the mine as a whole and the nominally computed costs, for the individual mining systems (Tables 4 and 5), which is basically caused by the differences in the share of wages, attests to serious shortcomings



in the norming and calculation of labor and wages; also, it attests to additional expenditures of labor and materials as a result of improper conduct of stoping work.

#### Change in Ore Extraction Costs for a Mine Whose Productivity Increases

Let us consider the changes in extraction costs in a mine whose resources warrant an increase in its productivity.\*

To investigate the dynamics of changes in expenditures and the order of the formation of shop costs according to the increase in mine productivity, it is necessary to determine which expenditures per output unit remain nominally fixed and which vary with increasing volume of extraction.

Below is cited a circumstantial, detailed estimate of the mine's production, with division of expenditures into nominally fixed and nominally variable.

The division adopted in Table 7 is of a nominal nature, because certain expenditure elements classified as nominally fixed may actually vary, i. e., they increase with increasing volume of output (for the mine as a whole), but to a lesser degree than the volume of output; hence, they decrease per output unit: e. g., the expenditures on the moving of loads, running repairs, and the like.

Inasmuch as the effect of a number of price-shaping factors on the magnitude of individual expenditures, according to change in the volume of output, has not been adequately explored (and, moreover, their share in production costs is small), therefore the proposed division of expenditures into nominally fixed and nominally variable can be utilized for calculating separately for every mining system the extraction cost per ton of ore under the conditions of a rising labor productivity.

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\*The question of capital investments is not considered in this article.

Table 7

Circumstantial Estimate of Production Expenditures  
(February 1956)

Element of Expenditure	Expenditures on Extraction of One Ton of Ore Rubles-Kopeykas	In Percent of Total	Division of Expenditures Rubles-Kopeykas	
			Nominally Fixed	Nominally Variable
1	2	3	4	5
<b>I. Auxiliary Materials</b>				
Timbering	3-85	4.46	-	3-85
Explosives	2-09	2.42	-	2-09
Time Fuse	0-32	0.37	-	0-32
Detonating Capsules	0-11	0.13	-	0-11
Pobedite	0-58	0.66	-	0-58
Drilling Steel	0-19	0.22	-	0-19
Carbide	0-58	0.67	0-58	-
Detonating Cord	0-24	0.28	-	0-24
Miscellaneous Materials	0-41	0.48	0-41	-
<b>Total</b>	<b>8-37</b>	<b>9.69</b>	<b>0-99</b>	<b>7-38</b>
<b>II. Wages and Bonuses</b>				
<b>1. Basic Group:</b>				
Stope Workers	22-11	25.59	-	22-11*
(Underground) Transport Workers	3-65	4.22	-	3-65
Flushers (At Extraction and Transport)	1-12	1.30	-	1-12
<b>Total</b>	<b>26-88</b>	<b>31.11</b>	<b>-</b>	<b>26-88</b>
<b>2. Auxiliary Group:</b>				
Medical Service Workers	2-65	3.07	2-65**	-
Ventilation Workers				
Explosives-Depot Workers				
Power Service Workers				
Administrative Workers	0-46	0.53	0-46	-
Workers of the Geologic and Mine-Surveying Section	0-58	0.67	0-58	-
Hoist Workers	1-48	1.71	1-48	-
<b>Total</b>	<b>5-17</b>	<b>5.98</b>	<b>5-17</b>	<b>-</b>

Table 7 Continued

Element of Expenditure	Expenditures on Extraction of One Ton of Ore Rubles-Kopeckas	In Percent of Total	Division of Expenditures Rubles-Kopeckas Nominally Fixed    Nominally Variable	
1	2	3	4	5
3. Wages in Complex Items**:				
Wages of Workers	9-21	10.66	9-21	-
Wages of Engineer-Technician Personnel and White-Collar Workers	7-50	8.68	7-50	-
Compressor Workers	0-36	0.42	0-36	-
Total	17-07	19.76	17-07	-
Grand Total, Wages	49-12	56.85	22-24	26-88
III. Electric Power,				
Hoisting of Ore	0-95	1.10	-	0-95
Water Drainage	0-38	0.44	0-38	-
Underground Transport	0-41	0.47	-	0-41
Compressor Station	1-20	1.39	-	1-20
Ore Delivery	0-50	0.58	-	0-50
Total	3-44	3.98	0-38	3-06
V. Amortization**	8-95	10.36	8-95	-
Payment of Mine-Development Costs	5-19	6.00	-	5-19
VI. Overhead Expenses				
Current Repairs of Basic Assets**	3-62	4.19	3-62	-
Upkeep of Basic Assets*	1-80	2.08	1-80	-
Moving of Loads	1-12	1.29	1-12	-
Labor Safety	3-86	4.47	3-86	-
Miscellaneous Expenses	0-81	0.94	0-81	-
Servicing of Drills	0-13	0.15	0-13	-
Total	11-34	13.12	11-34	-
Combined Grand Total per Ton of Ore	86-41	100	43-90	42-51

Table 7 Continued

- \* In the event the volume of output increases as a result of improvements in mining systems the wages of stope workers will be nominally fixed
- \*\* Assumed to be nominally fixed, for simplicity of calculations.

In the example considered here, at a fixed number of stope workers, the rise in their labor productivity will entail a commensurate proportional rise in ore extraction. If we adopt the level of labor productivity per stope worker according to various mining systems as determined by the computational method (cf. Byulleten' TsNII MTsM SSSR /Bulletin of the Central Scientific Research Institute of the Ministry of Nonferrous Metallurgy USSR, No 18, 1956), upon lowering it in advance by 15 percent to take account of unforeseen operations, then the computed volume of output should increase and be as follows according to the various mining systems, as compared with the actual volume of output (in percent):

By horizontal layers with flushing	117
By sublevel drifts Without Flushing of chambers	136
Ditto, with flushing of chambers	515
By blocks with forced caving	515

The extraction costs per ton of ore under the conditions of the postulated rise in production according to the individual mining systems will decrease to the level cited in Table 8.

Table 8

	Mining System			
	Horizontal Layers With Flushing	Sublevel With Chamber Flushing	Drifts Without Chamber Flushing	Forced Block Caving
Extraction Costs per Ton of Ore (in rubles and kopeykas)	72-42	64-96	28-96	26-64
Ditto, But in Percent of Extraction Costs for Each Mining System as Compared With the Existing Level of Output	91.8	84.7	44.8	42.8

The above-cited extraction costs according to various mining systems under the conditions of a postulated rise in output were calculated in the following manner:

(1) The costs of materials, wages for the group of stope workers and payment of mine-development costs were calculated according to the mining systems on the basis of the norms, wage rates and list prices of materials effective at the mine;

(2) The outlays on the other expenditure items were calculated on the basis of the data of Table 7 upon revising the nominally-fixed expenditures, so as to take into account the rise in output according to the mining system.

A substantial decrease in extraction costs ensuing from a rise in extraction will, in turn, alter the structure of these costs, basically as a result of the steep decrease in the percentile share of overhead expenses (Table 9).

Table 9

Structure of Extraction Costs Under the Conditions of a  
Postulated Rise in Extraction, in percent of total

Item of Expenditure	Mining System			
	Horizontal Layers With Flushing	Sublevel Drifts		Forced Block Caving
		With Chamber Flushing	Without Chamber Flushing	
Auxiliary Materials	10.87	10.87	14.40	15.02
Wages	53.20	51.96	40.81	43.95
Electric Power	4.67	5.13	10.80	11.75
Amortization	10.56	10.13	6.01	6.53
Mine-Development Costs	7.32	9.08	20.38	13.88
Overhead Expenses	13.38	12.83	7.60	8.86
TOTAL	100	100	100	100

Thus, the increase in the volume of extraction in the mine is a principal factor in determining the level of extraction costs, as confirmed by the data of an approximate calculation (Table 10).

Table 10

Decrease in the Extraction Costs per Ton of Ore Upon a  
Doubling of the Labor Productivity of Stope Workers In  
Mines With a Fixed and an Increasing Output, Respectively

System of Mining	In Mines With A Fixed Output		In Mines With an Increasing Output	
	Absolute Decrease rubles- kopeykas	in percent	Absolute Decrease rubles- kopeykas	in percent
Horizontal Layers With Flushing	by 7-30	or by 10.0	by 26-60	or by 36.5
Sublevel Drifts With Flushing of Chambers	by 6-25	or by 8.0	by 22-67	or by 35.0
Ditto, Without Flushing of Chambers	by 2-95	or by 4.5	by 6-14	or by 21.0
Blocks With Forced Caving	by 2-31	or by 3.8	by 6-29	or by 23.5



Consequently, the introduction of a productive mining system will be properly effective economically only upon increasing the mine output.

#### The Effect of Depletion on the Ore Extraction Costs

Having been adopted in many ore-mining enterprises, the procedure of calculating expenditures per ton of extracted ore and not according to the metals in the ore does not reveal the effect of the working-out of ore on a rise in the cost of metals, whose extraction is the purpose of the operations. If, in general, in our calculations of production costs we do not adopt one ton of ore but a definite amount of metal in the ore as the output unit, then the depletion in the process of extraction will result in a major change in the extraction costs of the metal.

The following relationship exists between the expenditures on one ton of ore at bulk extraction inclusive of gangue interlayers and the expenditures on one nominal ton of ore with a definite amount of metal:

$$V_1 = \frac{V}{100-P} \times 100 \quad (1)$$

where  $V_1$  is cost of nominal ton of ore (i. e., of ore with a definite amount of metal)

$V$  is cost of technological ore at bulk extraction (as taken from Table 5)

$P$  is percentage of the depletion (working-out) of ore.

In our concrete example the gangue interlayers account for 32 percent (cf. Byulleten' TsNII MTsM SSSR, No 18, 1956).

The extraction costs per ton of nominal ore (i. e., for a definite amount of metal contained in one ton of ore) according to various mining systems in a mine with a fixed output will be as follows (in rubles-kopeykas) for these mining systems:

Sublevel drifts with flushing of chambers 112-82

$$\left( \frac{76.72}{100-32} \times 100 \right)$$

Ditto, without flushing of chambers 95-17

Blocks with forced caving 91-75

Extraction by the system of horizontal layers with flushing makes it possible, in the given concrete case, to conduct selective working of ore; hence, the extraction costs per ton of ore at this system, set at 78 rubles 89 kopeykas (see Table 5), are adopted as the basis for judging the profitability of the other systems.

As can be seen from the above-cited data, under the conditions of a fixed output of the mine the employment of the systems of extraction by sublevel drifts and by forced block caving, at which earthy matter will account for 32 percent of the extracted ore and the extraction costs per ton of ore will commensurately rise to 113 rubles 95 kopeykas and 92 rubles, respectively, is not profitable. It is also obvious that the limit of profitability of the system with increased productivity per stope worker, but, with a higher percentage of earthy matter in extracted ore, will be reached when the extraction costs per ton of nominal ore ( $V_1$ ) under the new system become equal to the costs per ton of the gross ore extracted by the previously used system, i. e.

$$V_1 = A = \frac{V}{100-P} \times 100 \quad (2)$$

where A is actual cost per ton of ore extracted by the previously used system, in which extraction could be conducted more selectively or with a smaller percentage of earthy matter.

Converting formula (2) in relation to P

$$P = 100 - \frac{V}{A} \times 100 \quad (3)$$

it is possible to determine the economically permissible percentage of earthy matter for any mining system involving the bulk extraction of ore, as compared with extraction by more productive systems.

In our case, for a mine with a fixed output, the systems with the gross extraction of ore will be profitable only if the extraction cost per ton of nominal ore will not be higher than 78 rubles, 89 kopeykas and the percentage of earthy matter will not be higher than -- for the system of sublevel drifts with flushing of chambers\*--2.7, i. e.,

$100 - \left( \frac{76.72}{78.89} \times 100 \right)$ ; for the same system but without flushing of chambers -- 18; and for the system of blocks with forced caving -- 21.

Inasmuch as the earthy matter accounts for 32 percent

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\*The extraction cost per ton is taken from Table 5

of the extracted ore, and since for the above-mentioned mining systems the percentage of earthy matter will not be below 32 percent, therefore, the employment of these systems will not, as shown by the calculation according to formula (3), be profitable.

In the case of mines with a rising output (see Table 8), assuming the percentage of earthy matter in its extracted ore to approximate 32 percent, the extraction cost per ton of nominal ore calculated according to formula (1) will be as follows (in rubles and kopeyks) for these mining systems:

Sublevel drifts with flushing of chambers 95-50

$$\left( \frac{64.96}{100-32} \times 100 \right)$$

Ditto, without flushing of chambers 42-60

Blocks with forced caving 39-20

The limit of the permissible percentage of earthy matter in extracted ore, as calculated according to formula (1), for these mining systems will amount respectively to

17.6 percent. =  $100 - \left[ \frac{64.96}{78.89} \times 100 \right]$ , 63 percent and 66 percent.

Consequently, in the given case, compared with the selective extraction of ore by the method of horizontal layers with flushing, only the systems of extraction by sublevel drifts without flushing and by blocks with forced caving are profitable. The permissibility of such a high degree of earthy matter in extracted ore in the case of rising extraction is proved by the following simple example: Let us assume that a selectively worked ore contains 100 kilograms of metal; on increasing the extraction of that ore fivefold and extracting it unselectively (with 66 percent of earthy matter), we obtain the following amount of metal:  $(100-66) \times 5 = 170$  kilograms.

The determination of the effect of unselective extraction on the production costs of metal in the concentration products involves known difficulties. Laboratory investigations and practice show that when the metal content of an ore decreases, then the metal content of the concentration tailings also decreases somewhat; in every case, however, the losses increase. The permissible limit of the gangue content of ore is determined on the basis of the ratio of the actual (previous) production cost to new cost, as calculated on taking into account the increasing mine productivity, after adding in both cases the expenditures on the processing of ore:

$$P = 100 - \left[ \frac{V + C}{A + C} \times 100 \right] \quad (4)$$

where A is actual shop cost known from bookkeeping accounts  
C is cost of processing one ton of ore.

To determine the new (reduced) production cost V, a calculation by elements of expenditures, with separate sub-calculation of the nominally-fixed and nominally-variable expenditures (Table 7), is carried out.

Let us illustrate the calculation of the permissible percentage of gangue by the following isolated example:

- A -- Existing extraction cost per ton of ore, amounting to 90 rubles;
- V -- New extraction cost, reduced to 70 rubles as a result of the employment of the bulk extraction system;
- C -- Cost of processing one ton of ore, amounting to 55 rubles. As calculated according to formula (3), the permissible percentage of gangue under the new system will, on disregarding the processing of ore, amount to 22.3 percent.

$$P = 100 - \left[ \frac{V}{A} \times 100 \right] = 100 - \left[ \frac{70}{90} \times 100 \right] = 22.3 \text{ percent.}$$

On taking into account the expenditures on the processing of ore, the permissible percentage of gangue declines to 13.8 percent:

$$P = 100 - \left[ \frac{V + C}{A + C} \times 100 \right] = 100 - \left[ \frac{70 + 55}{90 + 55} \times 100 \right] = 13.8 \text{ percent.}$$

As can be seen from the foregoing, the economic expediency of employing bulk-extraction systems, which make it possible to increase the productivity of a mining enterprise and reduce the ore extraction costs, depends on the extent of the increasing depletion of ore.

#### Conclusions

1. The mining systems involving the bulk extraction of ore reduce shop costs more effectively (and increase labor productivity), if their application is accompanied by a

commensurate increase in the volume of extraction.

2. The system of stope extraction does not, by itself, determine the level of technical-economic indexes. These indexes depend on a number of factors, including the capacity and state of equipment, the suitability of machinery to given mining-technical conditions and its adequate productivity at every stage of the technological process of the extraction and haulage of ore, and, lastly, the efficiency with which the process as a whole is managed.

3. Ore with a high content of gangue raises considerably the costs of metals in the process of their extraction and, especially, concentration. Therefore, the conversion to a bulk-extraction system, in which ore with a high gangue content is extracted, requires a careful study in every individual case.

4. Under any conditions, wages and overhead expenses account for the principal items in the ore extraction cost, reaching 70 to 78 percent of that cost. Consequently, the factors important in reducing extraction cost include not only the technical perfecting of mining systems but also -- and primarily -- organizational measures, on the scale of the enterprise as a whole, for increasing the labor productivity of workers, expanding the volume of output, improving the utilization of machinery, reducing the number of auxiliary personnel, reducing the outlays of auxiliary materials, and so forth.

\* \* \*

Although the basic data of this study refer to a particular case and the obtained figures are to some extent theoretical in nature -- because, in practice, a fivefold increase in extraction solely by adopting a new mining system would hardly be feasible without some expansion of individual auxiliary services and shops -- nevertheless the above-cited methods of calculating extraction costs according to labor productivity, volume of output and gangue content in bulk extraction of ore, as well as the order of magnitude of these figures, apply for any ore mine.

## 5. Development of the Degtyarsk Mine

[This is a translation of an article written by Ye. G. Rudak in Byulleten' Tsvetnoy Metallurgii, No 19/20 (96-97), pages 27-29.]

The History of the Mine. The Degtyarsk Deposit was discovered at the end of the Nineteenth Century. Initially, the limonites of the iron cap of the pyrite bed were extracted.

The working of the pyrite ores of the Degtyarsk Deposit was begun in 1914. In the northern part of the deposit, gray pyrite was being mined by open-strip methods for the plants of the chemical industry.

Between 1918 and 1926 the deposit was shut down, but in 1926 it was reopened -- though for a short time only -- by the British "Lena-Goldfields" company. The British concessionaires, who rejected the demands of the workers, were forced to abandon the mine. During their operations the ore was extracted only from the richer parts of the deposit. Mine shafts were sunk at distances of 20 to 25 meters from the footwall of the ore body, which made it possible to work the deposit from these shafts only to a depth of 70 meters.

Beginning with 1931 extensive exploration activities were conducted in the deposit; these were followed by the start of the construction of a new mine accompanied by the development of stoping work from the already existing shafts. The exploratory activities revealed enormous reserves of cupriferous and gray-pyritic ores: in 1937 the category -A+B Industrially exploitable ores accounted for 57 percent of all proven copper-ore reserves of the Urals. Instead of a great number of small shafts two capital shafts were sunk into the footwall of the deposit, so as to ensure the working of the deposit to a depth of 800 meters.

Since 1931, ore extraction at the Degtyarsk mine had been continually increasing, and in 1956 it was brought up to its full level.

The increase in ore extraction was achieved by mastering the entire area of the deposit, mechanizing the production processes, perfecting the mining systems, and organizing socialist labor competition.

Development of Mining Systems. Considerable changes have occurred in the methods of ore extraction. At the mine, at present, labor-consuming mining systems such as extraction from horizontal layers with flushing and square-set timbering are being gradually supplanted by the systems of sublevel drifts and sublevel caving (Fig. 1).



Upon the working of blocks by the system of layer caving the layer height was increased from 2.5 to three meters, which raised the labor productivity per stope worker by 30 percent and reduced the consumption of timbering and explosive charges and materials.

The stope-wall method was applied for working several inter-chamber blocks by the system of layer caving, and this made it possible to increase the labor productivity of the workers in the stope group by 30 to 35 percent. There was introduced prophylactic silting-up, which made it possible to reduce the fire hazard of the sublevel-caving system and to apply that system on a broader scale.

The systems of sublevel drifts and sublevel caving were complemented by the extraction of ore from deep boreholes. The drilling of the holes is conducted with BMK-2 and BMD-50 machines instead of telescoping drills, a fact which has considerably increased the productivity of the system.

The caving of blocks into foundationless chambers by mass explosions was the subject of several tests; this has yielded satisfactory results and has also revealed the possibility of employing this system in the working of deposits with a high fire hazard.

Experimental studies are being conducted with regard to applying the system of sublevel caving with a 20-meter height of sublevel in the Degtyarsk Mine.

Mechanization of Production Processes. During the years of Soviet power the labors of the miners in Degtyarsk have been greatly eased by the mechanization of the basic production processes. The manual loading of ore with a shovel and its hauling in wheelbarrows have now been supplanted by gathering by scrapers and loading by mechanical loaders. As of 1 July 1957, 515 scraper installations, 25 PML-5 loading machines, two BCh-1 loaders and 48 electric locomotives were operating in the mine.

For its conduct of drilling operations the mine is equipped with 850 high-productivity manual, telescoping and column drills, 19 machines for the drilling of deep boreholes, and 11 drilling carriages.

Not only the basic production processes but also many auxiliary processes have been mechanized. The heavy manual labor involved in exchanging the mine cars in the shaft cage has been liquidated, an electric machine tool for framing mine timbering has been developed and applied, and pneumatic-drive sector gates of ore chutes have been successfully applied.

Automation is being applied on a broad scale. It has been extended to the control of ventilation ports, shaft

doors on mine yards, and pumping and heating installations. High-frequency communication and STsB /Signaling-Centralization-Block/ systems are being introduced in underground transport. In 1957-1958 the operations of the compressor and ventilation stations will be automated. In the immediate future remote control of electric locomotives at ore-loading and -unloading points will be introduced in the mine.

High-Speed Tunneling of Levels. To increase substantially ore extraction at the mine it was necessary to prepare an appropriate stoping area, which required an accelerated tunneling of mine levels and entries. Until 1947 the maximum tunneling rate did not exceed 45 meters a month. In 1947 two brigades for the high-speed tunneling of entries were organized. These brigades were equipped with drilling carriages for two- and four-core drills, and with loading machines, and their operations were conducted according to a "cyclogram." As a result, the average rate of the headway exceeded 50 running meters a month.

As of 1955, in addition to the organization of the high-speed tunneling of capital levels, the high-speed methods were also introduced in stope operations.

By perfecting the technological process, utilizing highly productive machinery and introducing improved methods of the organization of labor the tunnelers' and miners' brigades have been, year after year, attaining an ever greater increase in tunneling rate and in labor productivity (Fig. 2).

The tunneling brigade headed by N. S. Krivobok achieved a mean monthly tunneling rate of 100 to 110 running meters. In March 1957 this brigade had already tunneled 230.1 running meters; the productivity of the tunneler amounted to 5.65 cubic meters per shift.

Labor productivity in the brigade headed by F. Petrovskiy, while tunneling levels close to the shaft of the Kapital'naya 2 Plant, has reached four to four and one half cubic meters per shift worker.

The stope brigades headed by F. I. Shabanov, N. Gimayev, N. I. Sushkov, A. M. Namedov, I. A. Pleshivikh, V. P. Storozhenko, and V. G. Armaninov, are producing 3,000 to 4,500 tons of ore monthly, thus ensuring an advance of the stoping belt by 100 to 150 running meters; in this connection the productivity per worker per shift ranges from four to six and one half cubic meters of ore (the mean productivity per stope worker for the Mine as a whole is 2.85 cubic meters).

Every high-speed stope brigade consists of from seven to 15 stopers working on two to four stopes (the normal

brigade consists of three to five persons).

The auxiliary workers -- the timberers and scraper operators -- service specific high-speed brigades; their wages depend on the number of traversed meters of stope area. This stimulates their work and improves their servicing of the brigades.

The creation of high-speed brigades at the mine has made it possible to execute the transition to a greater (three-meter) layer height in the layer-caving system, to apply flexible flooring three and one half to four meters long instead of two and one half meters, which makes it possible to drill holes 1.5 meters deep in the stoping belts, and to introduce, in a majority of cases, double scraping of ore from the belts; this, in turn, reduces considerably the expenditures of time on the gathering of ore.

Welfare of the Mine's Employees. In 1954 the mine workers' settlement has been renamed the town of Degtyarsk. The cluster of barracks and wooden houses is being replaced by a town of stone with macadamized streets, adorned with greenery, schools, motion picture theaters, and specialized stores.

In the first year of the Sixth Five-Year Plan (later changed to the Seven-Year Plan) the population of Degtyarsk was provided with 17,600 square meters of dwelling area, a palace of culture, and a polyclinic; in addition, the construction of a hospital compound is being completed.

During the forthcoming five-year period the scale of new construction will be further broadened. New kindergartens and creches, public baths, a motion picture theatre, a canteen and a new sports stadium will be built; the town's inhabitants will be provided with an additional 25,000 square meters of dwelling area.

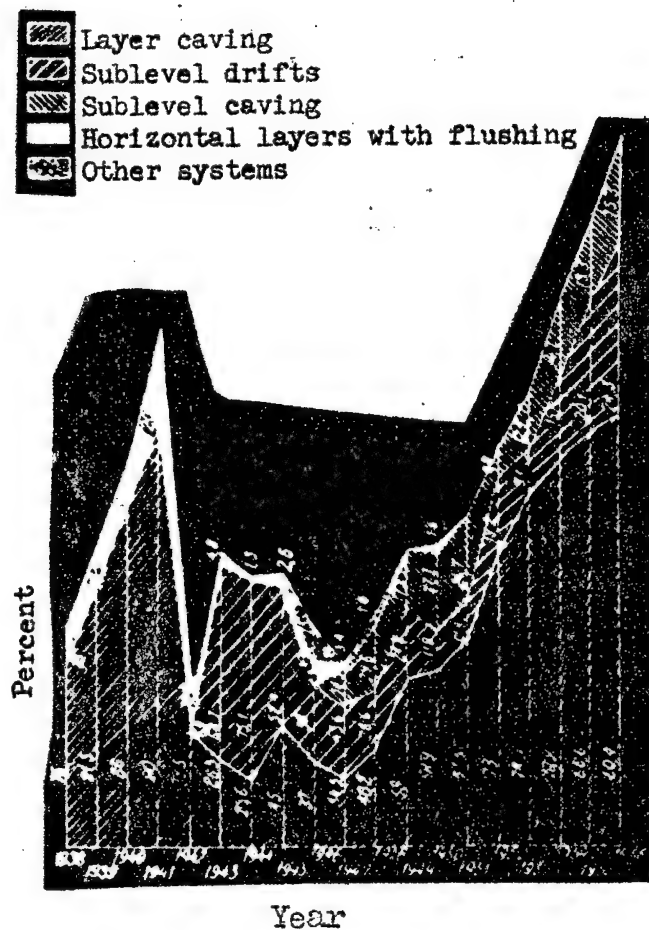


Fig. 1. Graph of Ore Extraction According to Mining System (in percent).

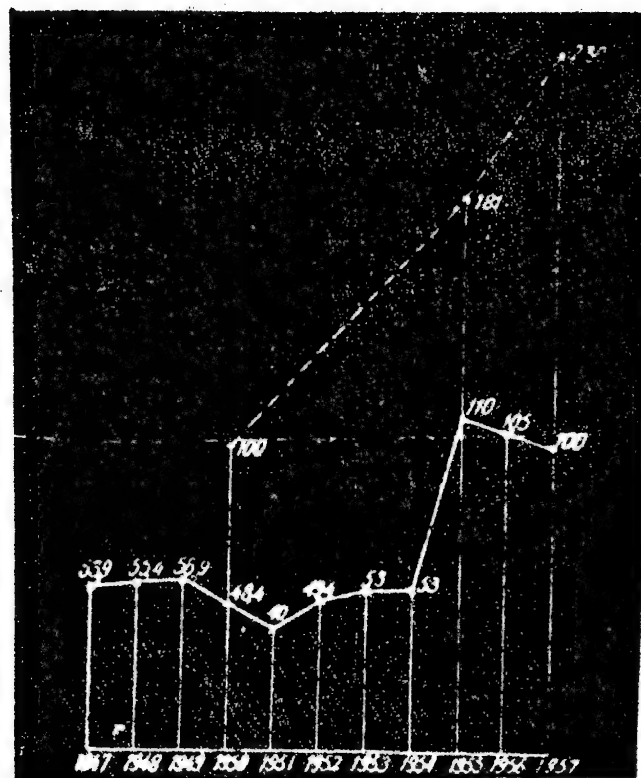


Fig. 2. Graph of the Tunneling of Mine Levels by the Best Tunneling Brigades

- - - - maximal monthly tunneling rates (in running meters)  
 ————— average monthly tunneling rate over a year (in running meters)



## 6. The Raw Material Base of the Nonferrous and Rare Metals Industry During the Past Forty Years

[This is a translation of an article written by A. A. Amiraslanov in Byulleten' Tsvetnoy Metallurgii, No 19/20 (96-97), 1957, pages 13-26.]

Russia entered the Twentieth Century with a feebly developed industry. The roster of the nonferrous, rare and noble metals extracted in Russia was confined to copper, lead, zinc, and gold. Despite its vast territory, large population and huge mineral resources, the country had extracted in 1913 only a little more than 3,000 tons of lead, about 31,000 tons of zinc, and about 30,000 tons of copper. In that year, also 4.4 million tons of pig iron and 4.2 million tons of steel were smelted in Russia.

To visualize the degree of backwardness of Tsarist Russia, it is enough to compare, e.g., the smelting of zinc in various countries in 1910. The USA had then smelted 251,000 tons, Germany -- 288,000 tons, England -- 63,000 tons, and Russia -- 9,000 tons. Even Spain had smelted six and one half times as much zinc -- 59,000 tons.

Since it utilized its mineral resources with exceptional inefficiency, Russia was unable to develop its own machine building industry and could not free itself from its economic enslavement by the leading capitalist countries.

The extraction of nonferrous metals in Russia was basically conducted by foreign concessionaires, who were uninterested in a planned exploration of Russia's riches and therefore made predatory attempts to exploit the richest ores. The low demand for nonferrous and rare metals was satisfied by imports from other countries.

Prior to 1918 about 70 percent of the country's area remained unexposed to any geological surveys at all. Only 25.2 percent of the country's entire area was surveyed on the scale of from 1:2,000,000 to 1:1,000,000, and only 2.4 percent on the scale of 1:200,000 and larger. Maps of the most necessary scale of 1:50,000 and larger were generally lacking.

The Tsarist State did not establish and develop scientific-research and practical geologic-prospecting organizations. There existed only a few organizations, including the "Geol-kom" [Geological Committee] (now "VSEGEI") [All-Union Scientific Research Geological Institute], the Academy of Sciences, and small geological cells in the higher educational institutions of the larger cities. Their activities were considerably restricted by the smallness of their subsidies.

Academician V. I. Vernadskiy wrote as follows

regarding the studies of mineral raw materials in Russia at the turn of the century: "We do not have a single up-to-date State laboratory. The research institutes are just being born, and Lomonosov Institute of the Academy of Sciences is still only in the planning stage. There are no active institutes. Not only the dwarf research cells in the educational institutions but also the principal center of scientific research -- the Academy of Sciences, whose membership includes world-famous scientists -- are leading a miserable existence. Until very recently, and partly also into the present, a number of the Academy's institutions have been niggardly equipped."

A nearly identical characterization of the state of basic- and practical-research institutions and the conduct of research in pre-Revolutionary Russia has been provided by academicians A. Ye. Fersman, I. M. Gubkin, and others.

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Attaching decisive importance to the uncovering of the mineral and raw material resources of the country after the Great October Socialist Revolution, the Communist Party and Soviet State have been displaying ceaseless solicitude concerning the development of geologic-prospecting activities. The directive for the intensified development of metallurgy was first given at the 13th Party Conference. The Central Committee of the VKP(b) [All-Union Communist Party (Bolsheviks)], regarding metal as the underlying basis of our industry, in its report at the 14th Party Congress had recommended that the balance of metals be brought up to par with the balance of industry and transport. The 15th Party Conference issued a directive for the re-equipment and modernization of heavy industry and, in particular, for the devotion of sufficient attention to the development of the nonferrous metals industry (copper, tin, lead, aluminum).

The 16th Party Congress emphasized that "the safeguarding of the development of the national economy requires that geologic-prospecting activities proceed at a pace far in advance of the pace of industrial development, so as to assure a timely provision of mineral raw materials. For this purpose it is necessary to effect a decisive breakthrough in geologic prospecting activities and to ensure them with a material base upon revising appropriately the five-year plan of these activities."\*

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\*"The CPSU in the Resolutions and Decisions of its Congress Conferences, and CC Plenums," Part II, Seventh Edition, Gospolitizdat, 1953, Page 587

The 17th Party Conference paid special attention to the omnilateral studies and exploitation of mineral raw materials.

The development of geologic-prospecting activities and the expansion of mineral resources of the industry of ferrous and nonferrous metallurgy were the object of special attention at the 17th, 18th, and 19th Party Congresses, at the plenums of the CC CPSU, and in the directives for drafting the Third, Fourth and Fifth Five-Year Plans.

The Directives of the 20th Party Congress Concerning the Sixth Five-Year Plan of Development of the National Economy of the USSR in 1956-1960 state the following:

"8. To conduct, in 1956-1960, geologic-prospecting activities on a scale ensuring the necessary expansion of the mineral and raw material bases of the existing and newly planned enterprises, as well as the creation of reserves of proven resources of minerals for the further development of industry in, primarily, the country's eastern regions."

"To ensure an increase in the proven reserves of high-grade iron ores and nickel on the scale of 30 to 35 percent above the reserves proven at the beginning of the five-year period; and to ensure a corresponding increase of 40 to 45 percent in the reserves of copper, bauxites, titanium and boron raw materials; 50 to 55 percent -- in the reserves of niobium; 55 to 60 percent -- for lead and tin; 65 to 70 percent -- for molybdenum; 75 to 80 percent -- for mercury; 65 to 70 percent -- for crude petroleum; as well as an increase of 35 to 40 percent in the deposits of power coals and not less than 40 percent in the deposits of coking coals."\*

The 20th Party Congress cited the need for an omnilateral expansion of prospecting for new deposits of nonferrous and rare metals in the country's eastern regions.

Thanks to the constant solicitude of the Party and State, the geologists and geological organizations have been rapidly increasing the pace of their activities and improving their quality; during the 40 years of Soviet power, they have attained signal successes both in the field of the mapping and geological investigation of the country's territory and also in creating reliable raw material bases for the industry of ferrous and nonferrous metallurgy.

At present, only about three to three and one half percent of the country's area has still remained unexposed to

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\* "Directives of the 20th Party Congress Concerning the Sixth Five-Year Plan of Development of the National Economy of the USSR in the Years 1956-1960," Gospolitizdat, 1956, page 10

systematic geologic surveying (compared with 70 percent at the beginning of 1918). The percentile share of the large-scale surveys, necessary for prospecting-exploring and metallogenic activities, has increased considerably. In particular the percentile share of the geologic surveys on the scale of 1:200,000 and larger amounted to 38 percent as of 1 January 1955 compared with 2.4 percent on 1 January 1918, and the share of surveys on the scale of 1:1,000,000 amounts to 94 percent compared with the previous 27 percent.

All this has made it possible to conduct prospecting efficiently, and to discover and explore the raw-material resources of nonferrous and rare metals.

### Resources of the Copper Industry

Copper is one of the most ancient metals, and its production in Tsarist Russia was organized as long ago as before the times of Peter the Great. In the beginning stages of the copper industry, copper was smelted from cupriferous sandstones of the western slope of the Urals and from oxidized copper ores in carbonate rocks or in the contacts between these rocks and igneous rocks. Later on, the richer massive pyritic ores were extracted at depths reaching the level of the underground water table. The number of the exploited copper ore deposits was very limited. They lay in the Urals (western and eastern slopes), Transcaucasus (Kedabek, Allaverdy, Zangezur), and West Siberia (Yuliya, Glafira, and others); certain small (but rich) deposits were also exploited in Central Kazakhstan. There existed no statistics for the country as a whole. Judging from the limited extraction of copper in 1913, and also from the data of the First All-Union Conference on Nonferrous and Rare Metals (1932), the proven copper-industry resources used to be of a very modest size.

Toward 1927 extensive geologic and prospecting-exploring activities were developed in the Urals, Central Kazakhstan, Central Asia, the Altay Mountains, and to some degree, in the Caucasus.

An analysis of the geological data then available was used to outline correctly the further policies of the conduct of prospecting and prospecting-exploring activities. The cupriferous sandstones extending throughout the entire northern slope of the Urals for over a thousand kilometers in the meridional direction, and characterized by their dispersal in concentration over hundreds of sites, were not classified as primary objects: it was impossible to develop a large-scale extraction of ore and to apply pace-setting mechanization in such sites.

Deposits of a contact genesis were classified as secondary objects because of their complex morphology and the small size of their ore bodies. In 1928 the deposits regarded as most promising were the cupro-pyritic ores of the Urals and other regions of the USSR, and also the cupriferous sandstones of Dzhezkazgan, whose proven reserves at that time were small. This was shortly followed by the discovery of the industrial importance of the cupro-molybdenic veined mineralization of the Kounrad and Almalyk type.

Considering that the largest copper smelting plants lay in the Central Urals, it was there that the geological activities were begun. Having established the structural position of the explored pyritic ore bodies and the nature of the change in intervening rocks, between 1926 and 1936 the geologists had together with geophysicists discovered new large deposits (Krasnogvardeyskoye, Novo-Leninskoye, the group of Karpushinskiye and Levikhinskiye, Blyava, Sibayevskoye, Buribayevskoye, Bakr-Uzyakskoye) and had simultaneously expanded the proven reserves of the Degtyarsk Deposit, the Karabash group of deposits, and many other deposits.

Studies of the geology and petrography of the pyritic deposits in the Urals and Armenia by academician A. N. Zavaritskiy had led him to certain conclusions on the metamorphic genesis of these deposits.

As a result of the generalization of all data, the following principal currently held postulates on their genesis have been formulated:

The principal types of copper deposits in the URRS are pyritic, cupro-molybdenic, cupriferous sandstones, the deposits in skarns and miscellaneous deposits.

Pyritic Ore Bodies. These are a most valuable raw material containing a number of useful components. Gray-pyrite ores usually accompany cupro-pyritic ores and serve as a signpost for prospecting for the latter in the same region.

At the beginning of the Third Five-Year Plan the share of the copper resources in the cupro-pyritic ores amounted to 14.6 percent of the country's total copper resources, while at the beginning of 1957 it rose to 26 percent. On the other hand, at the beginning of the Third Five-Year Plan approximately 83 percent of all extraction resulted from this type of ore, whereas at the beginning of 1957, in connection with the construction of ore-mining enterprises on deposits of other types, the share of the extraction of copper from cupro-pyritic ores fell to 36.9 percent. Until 1928 no prospecting for, and investigation of, cupro-molybdenic veined-impregnated ores had been conducted in the USSR. The poor development



of the copper industry and the concentration of demand on high-grade ores used to prevent a more large-scale prospecting for, and exploration of, this comparatively low-grade (in content of copper) type of ore.

Only after the experience of foreign countries (United States, Chile) in mastering analogous ores was assimilated, were extensive geologic-prospecting activities unfolded beginning with 1928 in Central Kazakhstan and subsequently in Central Asia and the Transcaucasus. As a result of these activities and studies of this type of deposit (in Kounrad, Almalik, Boshcheku., and other sites), it was established that their content of copper and molybdenum is low but, at the same time, thanks to the favorable conditions of their occurrence (permitting open-strip mining) and the extensive scale of their mineralization, it is possible to extract these metals from them profitably.

The resources of copper and molybdenum in these deposits in 1938 were enormous, and with regard to copper they accounted for over one half of its over-all total (52.2 percent). However, as a result of the subsequent prospecting for other deposits, and despite the absolute increase in the resources of copper-molybdenum ores, the percentile share of these ores in 1957 accounted for only 21 percent of the over-all total (Fig. 1).

Notwithstanding their extensive resources, no extraction of copper from ores of this type was conducted prior to 1938 owing to the incompleteness of the construction of ore-mining enterprises, and at present, it accounts for 20.2 percent of the country-wide extraction of copper from cupriferous ores.

Cupriferous Sandstones. Until 1917 they were known in the form of small deposits and ore outcrops on the western slope of the Urals within the confines of Permskaya and Chkalovskaya oblasts, Tatarskaya, Bashkirskaya and Chuvashskaya ASSRs, in the Donets Basin, in the upper course of the Lena River and in Atbasarskiy Rayon (Central Kazakhstan). The largest currently known deposit of this type (in Dzhezkazgan) used to be poorly explored.

Geologic prospecting activities showed that the resources of copper in all these regions (except for Dzhezkazgan) are small, scattered through numerous small deposits and lodes. The Dzhezkazgan Deposit became, beginning from 1926-1927, subjected to intensive geological studies. Having investigated in detail the geologic-structure features of the Dzhezkazgan region, the team of geologists headed by academician K. I. Satpayev expanded its proven reserves and established it as a greatly promising region. The genesis of that



deposit was determined as hydrothermal.

As early as in 1938 the reserves of cupriferous sandstones in Dzhezkazgan became considerably expanded and accounted for 20.2 percent of the nationwide total.

At present, Dzhezkazgan's copper reserves account for approximately 26 percent of the nationwide total of such reserves. Since only a small part of the productive area of the Dzhezkazgan region was subjected to exploration, it is obvious that that region constitutes a huge copper-bearing basin. The extraction of metal from these ores is rising very intensively.

Toward the beginning of 1938 only 6.1 percent of copper was recovered from these ores, whereas at present this figure has climbed to 26 percent. In view of the extensive explored reserves and the high copper content in these ores, the recovery of metal from these ores is bound to increase further in the future; this, in turn, requires a further intensification of geologic prospecting work in this region.

The prospecting activities conducted during the fourth and fifth five-year periods showed that ores analogous to those of the Dzhezkazgan Region occur also in the northeastern part of Siberia.

With regard to this type of deposit the task of geologic-prospecting activities in the northeast of Siberia is to determine the industrial value and scale of the mineralization.

Copper Ores in Skarns. Their share in the total is low. Until 1917 small resources of these ores, concentrated within comparatively high-grade ores, were known to occur in the Urals -- in the regions of the Tur'insk ore mines, Gora Vysokaya, Gumeshevka, and others, and they were being exploited. Prospecting showed that these deposits are small and their ore bodies are morphologically very heterogeneous. Fairly extensive bodies of comparatively low-grade impregnated ores occur contiguously to solid high-grade ores (occurring to a limited extent). The complexity of the shapes of ore bodies and their small sizes hamper the employment of high-productivity mining systems (Fig. 2).

At present the ores of these deposits have been discovered in the regions of the Urals (Tur'ya, Gumeshevka, Yezhovskaya, and others), in Central Kazakhstan (the region of Sayak), Western Siberia (Minusinskiy Rayon), and others.

Miscellaneous Types of Deposits. There include: cupro-nickel-cobaltic with platinoids, lead-zinc deposits with copper, low-grade impregnated cupro-vanadic in gabbro, and others. Prior to 1917 the resources of copper occurring in such complex ores were not taken into account. The period from 1926

till the present has been marked by a considerable increase in the reserves of copper in sulfide-nickel deposits. The reserves of copper in the miscellaneous types of deposits at present account for 23 percent of the total. The most promising regions with regard to the growth in the reserves of copper are the Kola Peninsula, Krasnoyarskiy Kray, and the Altay Mountain Range. At present our country has consolidated its position as one of the richest countries in the world in regard to copper reserves.

In the future the prospecting and prospecting-exploring activities should be focused on the principal types of cupriferous deposits (cupriferous sandstones, cupro-pyritic ores, and cupro-molybdenic ores), and concentrated primarily on the territory of Central Kazakhstan, Urals, Caucasus, etc., as well as in the northeastern part of the country.

On the basis of the existing proven reserves, it will be possible, in the immediate future, to increase substantially the extraction and smelting of copper; for this purpose, it will be necessary not only to expand geologic-prospecting activities but also to accelerate the construction of ore-mining enterprises.

#### Resources of the Lead-Zinc Industry

Prior to 1917 the resources of lead and zinc were not included in Russia's statistics. Beginning with 1924, Soviet geologists resumed geologic and prospecting activity on the deposits then known (Urals, Altay, Transbaykal, Caucasus, Seacoast). This activity was concentrated chiefly on the lead-zinc deposits of the pyritic types and on the lead- and zinc-rich vein deposits. The other types, such as lead-zinc ores (in carbonate rocks and in skarns), were not known aside from small deposits in Nerchinsko-Zavodskiy Rayon and a single deposit in Ol'ga-Tetyukhinskiy Rayon.

Extensive prospecting-exploring activities revealed the presence of these metals in many of the country's regions. It became evident that the reserves of the pyritic deposits alone could not ensure the development of this branch of the national economy. Moreover, the rational geographical distribution of enterprises demanded the discovery of new zinc-lead deposits. As a result of prospecting-exploring activities, a number of new large ore regions was discovered as early as toward 1930 in Central and Southern Kazakhstan (Karatau, Dzhungarskiy Alatau), and in the Tadzhik SSR (Karamazar). Explorations were carried out in the Achisay Deposit (Karatau), Tekeli Deposit (Dzhungarskiy Alatau), and the Kansay Group (Karamazar).

The scale of the old, small lead-zinc deposits known prior to 1917 (Leninogorsk, Zyryanovsk, Sadon, Salair, and others) was considerably expanded.

Subsequently, new ore bodies and deposits were discovered both in the old and in the new regions; these include: Nikolayevskoye, Zolotoushinskoye, Sokol'noye, Zyryanovsk, Grekhovskoye II, Karchiginskoye, and others -- in the Altay; Uchalinskoye, Sibayevskoye, Buribayevskoye, Blyavinskoye, and others -- in the Urals; Altyn-Topkanskye, Aktyuzskoye, Buurdinskoye, and others -- in Central Asia; and Zgidskoye, Urupskoye, Madneul'skoye, and others -- in the Caucasus.

The proven reserves of lead and zinc have grown greatly at present; with regard to the reserves of these metals our country occupies the leading place in the world.

The explored deposits can be divided into these principal types: pyritic deposits, deposits in carbonate rocks, and miscellaneous types of lead-zinc deposits.

Lead-Zinc Deposits of the Pyritic Type. (Altay and Ural Type). These contain at present approximately 40 percent of all proven reserves of lead and 77 percent of all proven reserves of zinc. It is to be noted that the ores of these deposits are the most valuable ones, because they contain several useful components (lead, zinc, copper, sulfur, cadmium, gold, silver, and many dispersed elements). Some of these ores contain industrially exploitable concentrations of arsenic. Compared with other countries, the Soviet Union is the only country endowed with large resources of this valuable complex raw material. With regard to zinc this type of deposits provides a unique raw material.

Intensive studies of the geology of this type of deposits made it possible to shed a fuller light on the problems of ore formation, the process of pulsation, problems of zonality, and the structural conditions of the localization of mineralization. Future geologic-prospecting work on this type of deposit should be considerably expanded.

The resources of lead and zinc in this type of ore are substantial, and at the beginning of 1938 they accounted for 62.8 percent of the nationwide total; at the beginning of 1957, owing to the increase in the proven resources of lead in other types of ores, and despite the absolute increase in their extent, they accounted for 40 percent of the nationwide total (Fig. 3). At the same time the share of the extraction of lead from these ores climbed from 25 percent in 1938 to 44 percent at present (Fig. 4).

The copper-zinc variety of these ores is inherently the principal type of raw material for the zinc industry, and it accounts for over three fourths of the country's total

proven zinc reserves (Figs. 5 and 6).

Lead-Zinc Deposits in Carbonate Rocks. These types of deposits were nearly totally unexplored prior to 1917, aside from a few small ore bodies in Nerchinsko-Zavodskiy Rayon.

Prospecting and geological surveying of our country's territory and inspections of the corridors in numerous ancient "miracle" mines have revealed the considerable saturation of carbonate rocks with lead and zinc. Beginning in 1928-1929 extensive prospecting and exploring activities were started in regard to these types of deposits, and were centered chiefly in new regions within the confines of the Central Asian republics and the Kazakh SSR. Very shortly the region of the Karatau Range was found to contain the large extremely metal-rich Achisay Deposit, which provided a foundation for further intensive studies of the territory of that mountain range. The discovery and exploration of deposits of the Kansay Group date from approximately the same time.

On the territory of the Central Asian republics, Kazakh SSR, the Caucasus, and the Transbaykal, and also in other regions of the country, new deposits of this type were discovered. Recently their proven reserves of lead have increased considerably, and now account for 33 percent of the nationwide total reserves of this type. The reserves of zinc in this type of mineralization reached 11 percent of the nationwide total by 1957. The smelting of zinc from ores of these types of deposits accounted for 16 percent of the total zinc smelting at the end of 1956, whereas prior to 1938 it was not conducted at all.

The Lead-Zinc Deposits Occurring in Skarns. No forms of such types of deposits were known prior to 1917 -- except for Tetyukhe. After the Nineteen Thirties a number of such deposits was discovered in Central Asia and Central Kazakhstan (Altyn-Topkan, Kzyl-Espe, Gul'shad, Chalata, Kurganshinkan, and others) -- and a number of the related ore bodies, on the seacoast.

The characteristic features of the geologic structure of this type of deposit are:

(a) Same timetable as that of the skarns forming in the contact between igneous and sedimentary -- and more rarely -- arenaceous-slaty, rocks; the ore bodies while forming at the same time as the skarn bodies, do not always coincide with the area of the latter; there exist cases in which the ore bodies are found in limestones some distance away from the contact;

(b) The industrially exploitable mineralization usually is localized in structures either lying near the contacts or

branching out from them; the ore bodies have incorrect, complex shapes and are represented by ramifying tubular deposits;

(c) The tubular bodies in carbonate rocks at some distance from the contact may serve as indicators for discovering large ore bodies near the contact;

(d) Ore minerals form much later than skarn minerals, and the displacement of skarn by ore minerals marks itself clearly.

Miscellaneous Types of Lead-Zinc Deposits. These include lead-zinc deposits in sandstones (Dzhezkazgan type); deposits in sandstones, and in arenaceous-slaty and slaty rocks; lead-zinc deposits in the form of veins in igneous rocks, and lead-zinc deposits in ancient strongly metamorphized gneisses, crystalline slates and other slates. The share of lead and zinc reserves in the miscellaneous deposits is low. Of all such types of deposits the most interesting one within the USSR is the Dzhezkazgan type. The ores in quartz veins or in the form of stockwork in igneous rocks, and also the mineralization in arenaceous-slaty rocks, and others, contain small reserves with a complex morphology and irregular distribution of useful components....

### Resources of the Tin Industry

Prior to 1917 tin deposits were not explored or studied in the USSR. Until 1930-1931 the related prospecting activities were conducted on a small scale in the Transbaykal and the Kalbinskiy Mountain Range. Beginning in 1932-1933 the mineral resources of the USSR and also the known multi-component, copper, lead-zinc, gold, and other deposits became extensively explored and studied with regard to their content of tin. As early as in 1938 industrially exploitable tin mineralizations were discovered in the Seacocat, Transbaykal, Yakutiya (Kolyma), and certain other regions of the USSR. The proven reserves of tin at the beginning of 1957 were quite considerable, and the USSR is one of the world's leading countries with regard to its reserves of this metal. These reserves are concentrated in the tin deposits related to pegmatites, in quartz veins, and in the sulfidic-cassiteritic type of deposits.

Tin Deposits Related to Pegmatites. In these deposits tin is represented by cassiterite in pegmatitic bodies among granitoid rocks, and, more rarely, among arenaceous-slaty rocks.

Tin granitoids are usually represented by the more acidic varieties. The pegmatites diminish in thickness both in extent and in depth. The industrially exploitable



mineralization is distributed irregularly in the pegmatites in the form of nests and lenses. Here and there the tin minerals occur in a banded distribution, alternated by bands of quartz and feldspar.

It has been established that the strongly greisenized and albitized pegmatites and granitoids are, all other conditions being equal, the most promising rocks in which to prospect for industrially exploitable tin concentrations. The percentile share of tin held in resources of this type is very low and, at present, amounts to one percent (Fig. 7); the extraction of tin from them amounts to 0.5 percent (Fig. 8). Although these types of deposits played some role in the initial stage of the geologic prospecting for and exploration of tin, at present, in view of the unfavorable mining-technical conditions of the irregular distribution of useful components in pegmatites, and in view of the insignificant reserves, their role is negligible.

Tin Deposits in Quartz Veins. In the initial stage of prospecting and exploration these also played a major role. Compared with the pegmatitic type, this type is more advantageous with regard to its tin content, distribution of useful components, and comparatively stable morphology. Tin in this type is also chiefly represented by cassiterite. The cassiterite is accompanied by wolframite, beryl, topaz, tourmaline, and small amounts of pyrite, arsenopyrite, pyrrhotine, and -- more rarely -- chalcopyrite, sphalerite and galenite. The quartz-cassiteritic type usually localizes itself in granitoids and arenaceous-slaty rocks.

The tin deposits related to quartz veins can be classified as follows with regard to their content of minerals: cassiterite-quartz-topaz-feldspar; cassiterite-wolframite-quartz; and the cassiterite in greisens.

The Sulfidic-Cassiteritic Type of Tin Deposits. The investigation of and prospecting for this type of deposits were begun much later than for the first two types; however, their proven reserves of tin had rapidly increased, and toward 1938 they had greatly outdistanced the reserves of tin in the other types.

Deposits of the sulfidic cassiteritic type occur basically in the arenaceous-slaty effusive rocks and, to a smaller extent, in granitoids. In addition to cassiterite they contain stannite, chalcopyrite, galenite, sphalerite, arsenopyrite, and pyrrhotine. Moreover, many of them have an industrially exploitable content of lead and zinc, and the same can be said of molybdenum (molybdenite) and rare earths. Tin ores in certain of the deposits are accompanied by fluorite, beryl and topaz.



Deposits of this formation most often accompany rocks of the granodioritic series and, less often, the more acidic granites. Their ores contain a considerable amount of sulfides of iron, copper, lead, zinc, and arsenic, and also they contain chlorite, tourmaline, magnetite, hematite, albite, apatite, rutile, siderite, and skarn minerals.

The following varieties can be distinguished within this type of deposits:

(a) Cassiterite in skarns with sphalerite, chalcopyrite, magnetite, and scheelite (Pitkaranto Deposit);

(b) Cassiterite -- chlorite, sulfidic ores with some amount of tourmaline (veins of Ubogay, Voinov, Khrustal'naya, etc.);

(c) Cassiterite with sulfides of iron, arsenic, copper (veins of Aleksandrovskaya, Smirnovskaya, and others);

(d) Cassiterite with sulfides of lead and zinc (Stalinskoye Deposit);

(e) Cassiterite with sulfides of lead, zinc and molybdenum and with minerals of rare elements.

The role of deposits of this type is very great, and it will increase even more in the future.

These three types, established by academician S. S. Smirnov during the initial stage of the studies of tin deposits, have played a useful role in the correct orienting of prospecting-exploring role and in the further growth in the proven reserves of tin. The forecasts of S. S. Smirnov regarding the promising outlook for the sulfidic-cassiteritic type have been corroborated.

Further prospecting and exploring activities should be focused on the eastern regions (Seacoast, Yakutiya, Magadanskaya Oblast, Khabarovskiy Kray, Transbaykal, and others), and primarily on the sulfidic-cassiteritic type....

### Resources of the Aluminum Industry

The aluminum industry is a creation of Soviet power. Bauxite deposits have been discovered and explored in the Urals, Central Kazakhstan, Leningradskaya and Vologodskaya oblasts, Buryat-Mongolia, Krasnoyarskiy Kray, Ukraine, and Western Siberia. Nephelines have been prospected for and are being successfully exploited as an alumina raw material. The resources of nephelines are virtually inexhaustible. They have been explored on the Kola Peninsula, in Krasnoyarskiy Kray, Armenian SSR, and elsewhere. Alunites have been explored and prepared for exploitation in the Azerbaydzhan SSR. Deposits of andalusites, diaspores, sillimanites, sericites, and other types of alumina-bearing raw materials have

been discovered and are being explored and studied in the Transbaykal, Kazakh SSR, and elsewhere.

In 1933 the proven reserves of bauxites were increased 7.7 times compared with 1929, and 1938 -- 13.1 times, while, compared with 1929, in 1956 they had multiplied many times over (this includes the high-grade bauxites considered in the balance sheet of industry).

In the immediate future it is necessary to expand considerably the raw material resources of the aluminum industry, and primarily the high-grade bauxites in the country's eastern regions.

#### Resources of the Mercury and Antimony Industry

The only known mercury deposits on the territory of the former Russian Empire were the Nikitovskoye, with its small reserves of that metal, and also the Khpekskoye Deposit in Dagestan. Extraction of mercury was limited to high-grade ores and conducted on a small scale. Prior to 1917 no deposits of antimony had been discovered. At present the proven reserves of these metals have greatly multiplied in comparison with 1941.

The geographical distribution of the deposits has also changed radically. At present they are known to occur in Central Asia, the Donets Basin, Western Ukraine, the Caucasus, Gornyy Altay Range, Central Kazakhstan, Krasnoyarskiy Kray, Transbaykal, Kamchatka, and in other regions.

In the majority of cases mercury and antimony are found together and form complex deposits, although independent separate deposits of these metals are known to occur also. The rocks in which the mercury and antimony deposits most commonly form are the arenaceous-slaty and carbonate rocks.

Individual mercury deposits occur in the contact between igneous and sedimentary rocks (in the zone of hybrid rocks).

The deposits of antimony and mercury are characterized by a multitiered cumulation of mineralization in the stratigraphical cross section. The shapes of the ore bodies are extremely variegated, ranging from sheetlike bodies to tubes, lenses and distinctive complex "replacement bodies." It is to be emphasized that most of the currently proven reserves of these metals occur in comparatively low-grade ores.

#### Resources of Other Rare and Dispersed Elements

The Soviet Union is endowed with abundant resources of rare and dispersed elements (niobium, tantalum, zirconium,

lithium, beryllium, strontium, indium, gallium, selenium, tellurium, cadmium, and many others).

Prior to 1917 these metals were not even produced in small quantities.

Geologic prospecting and exploring work revealed in the USSR numerous independent deposits of certain rare elements, and also the presence of many of them in the multi-component ores of the deposits of other metals.

Numerous lead-zinc, copper, nickel, tin, tungsten, aluminum, and molybdenum deposits contain dispersed elements and serve as raw-material sources for many of these elements. Selenium, tellurium, cadmium, indium, thallium, gallium, rhenium rare earths, and other elements exist in the explored multi-component ores in amounts which can ensure the demand of the rare metals industry for a long time. In the majority of cases these dispersed elements have no minerals of their own but occur within the framework of the principal ore minerals.

The cardinal goal of further studies of the resources of these elements in multi-component ores is a detailed crystallochemical study of the principal minerals, so as to establish the form of occurrence and concentration of these elements in minerals, etc., and also a technological study of ores, concentrates, tailings, and the products of metallurgical reduction (dusts, cakes, crude metals, slags, etc.), because these involve a considerable concentration of dispersed elements and thus become veritable "deposits" of these elements.

The tasks of further investigations for expanding the raw material reserves in the independent deposits of rare elements (niobium, tantalum, zirconium, rare earths, lithium, beryllium, and others) consist in developing as broadly as possible the related activities in the country's eastern regions.

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The positive results of the expansion of the raw materials base of nonferrous and rare metals over the last 40 years have been achieved by expanding the volume and scope of geologic prospecting activities, creating a well-ramified network of scientific-research and practical geological institutions and organizations, and increasing the number of geologist cadres.

As a result of scientific foresight and correct orientation of geologic prospecting activities, Soviet geologists have attained outstanding results. The state of the proven reserves shows that our country has within a historically brief interval of time succeeded in expanding enormously its proven reserves of all nonferrous and rare metals.

The widely ramified network of modernly and fully equipped practical geological organizations and scientific-research institutes is, in addition to its everyday work of expanding the proven reserves of mineral resources, working out major theoretical problems in the field of geological sciences -- problems assisting in the effective conduct of prospecting and exploring activities on a high theoretical level.

Generalizing the tremendous volume of actual data, the geologists of the practical geological organizations and the scientists of the research institutions are occupied with clarifying the theoretical problems of ore formation and laws of the geographical distribution of the deposits of mineral resources under definite geological conditions as well as with developing effective criteria for prospecting for new deposits.

The fundamental problems of theory that are of great significance to practice include the following:

1. The principles of compiling metallogenic maps. This problem was first posed by Soviet scientists. On the proposal of the delegation of scientists from the USSR, the 20th Session of the International Geological Congress adopted a resolution establishing an organization for elaborating this problem, to be permanently active under the Congresses.

There is no doubt that further research in this field will provide the necessary foundations for compiling such maps both for individual countries and for entire larger regions. Such maps, which will take into account the circumstantially elaborated geologic-structural problems relating to individual ore centers or types of deposits of various metals, will, in the final analysis, make it possible to establish the necessary laws governing the conditions of the localization of the deposits of mineral raw materials.

2. One of the most important achievements of the geologists and scientific research workers of our country has been the drafting and publication of numerous maps. The work on compiling a composite geologic map of the USSR on the scale of 1:2,500,000, under the guidance of academician D. V. Nalivkin, which has been honored with a Lenin Prize, deserves special attention. Of the maps of individual regions we will single out the maps of Magadanskaya Oblast, Central Asia, Urals, Caucasus, and other regions of the country, and also the publication of numerous specialized maps -- gold occurrence, hydrochemical, hydrogeological, geomorphological, metallogenic, and others. The latter assist in clarifying general geological problems (stratigraphy, tectonics, vulcanism, metamorphism, etc.) on a more broad plane and -- by the same token -- in basing the prospecting for deposits on scientific foundations.

3. The theoretical research in geochemistry has been

considerably intensified. The classical works of academicians V. I. Vernadskiy and A. Ye. Fersman in geochemistry during the last few decades are famous not only in our country but also abroad. Further researches at the Institute imeni Vernadskiy, the IGEM AN SSSR and in the academies of union republics (research in the application of isotopes, etc.) will undoubtedly enrich this science.

4. The problems of the geochronological scale are at present studied at the VSEGEI [All-Union Geological Scientific Research Institute], in the research institutions of the Academy of Sciences USSR in Leningrad, Moscow, and its local affiliates, and in the academies of sciences of the union republics, branch scientific-research institutes, and practical geologic-prospecting organizations. In this field a great deal [of work] remains to be done.

5. The classification of endogenic deposits of metallic mineral resources on the basis of thermodynamic factors (pressure and temperature) solely has not satisfied the needs of prospecting for and exploration of deposits. At present, it has been clearly established that such a classification is in the majority of cases a formal one, and that on the basis of various temperatures and pressures it is not possible to delineate clearly and isolate these groups of deposits and to transmit commensurately to the prospecting geologist the necessary criteria for further prospecting. Soviet geologists have offered various principles of classifying mineral deposits, such as, among others: classification according to the content of principal minerals (mineral formation); according to the enclosing rock formations, structural conditions of ore centers, and degree of metasomatism. Many geologists also believe that the postmagmatic part of the classification of the deposits of metallic minerals should be elaborated separately for individual metals or groups of related metals: for copper, lead, zinc, etc. It is necessary to continue these researches so as to devise a more orderly and practical classification.

6. Soviet geologists are intensively occupied with the processes of the metamorphism of both the montane rocks and the ore deposits, inclusive of the process of metasomatism. These researches have already yielded much information and will indisputably prove still more fruitful for understanding the role of intrusive and effusive processes, tectonics, ore-bearing therms (ascending and descending), in metamorphic processes, as well as the role of the regional processes of metamorphism. Upon decoding the course and results of these processes it will become possible to shed light on the formation of mineral deposits, to solve the riddle of the

nature of the neogenic formations arising in the contacts between ore bodies and their enclosing rocks, etc.

7. Scientific research institutions are widely concerned with regional and local tectonics, and notable results have been achieved in this field. The tectonic maps of various editions, especially the most recent ones, exhibited at the 20th Session of the International Geological Congress, demonstrated the high level and achievements of tectonic science in the USSR.

In the next few years geologists and researchers should relate regional tectonics to the tectonics of ore fields on giving special attention to the isolation of productive tectonic structures.

8. Special emphasis should be placed on the problems of the methods of the prospecting for and exploration of deposits. The geologists of the Soviet Union have made substantial advances in this field. All the currently existing manuals on the methods of mapping, prospecting, exploration, and rational surveying, as well as various instructions and methodological directives, attest to the fact that we are ahead of the other countries; however, we have much to accomplish in regard to the studies of the country's geological structure and its mineral resources.

It is necessary to bring about a greater rapprochement between the thematics of scientific research and the needs of industry. The solving of the proper geographical distribution of research institutions should be speeded up. The presence of numerous specialized scientific-research institutes and laboratories in various parts of the country makes it a pressing need to improve the aspects of the coordination of the problems, topics and methods of research so as to avoid duplication.

The geological community of our country, now commemorating the Fortieth Anniversary of the Soviet Socialist State, can be legitimately proud of its achievements in the field of developing the raw material resources of nonferrous and rare metals.



On 1 January 1938

On 1 January 1957

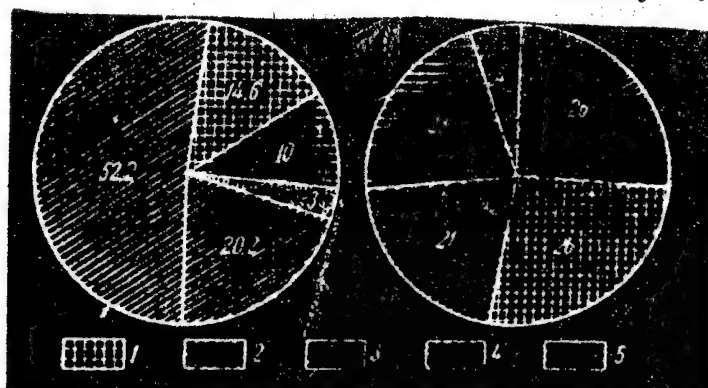


Fig. 1. Changes in Proven Reserves of Copper (in percent):  
 1. In cupro-pyritic deposits; 2. In cupriferous sandstones; 3. In cupriferous skarns;  
 4. In cupro-molybdenic deposits; 5. In miscellaneous deposits

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1 January 1957

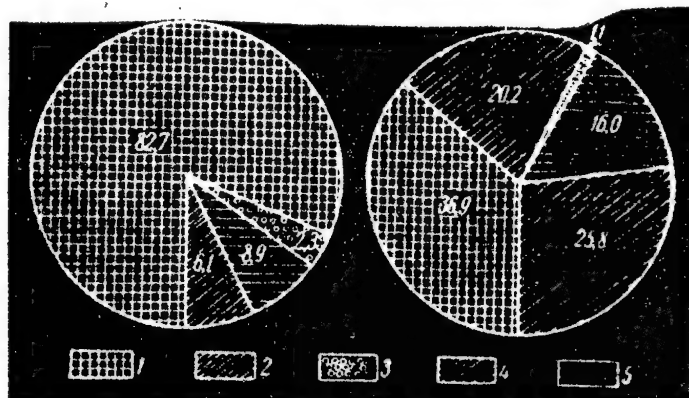


Fig. 2. Changes in the Extraction of Copper (in percent):  
 1. From cupro-pyritic deposits; 2. From deposits of cupriferous sandstones; 3. From skarn deposits; 4. From cupro-molybdenic deposits; 5. From other types of deposits.

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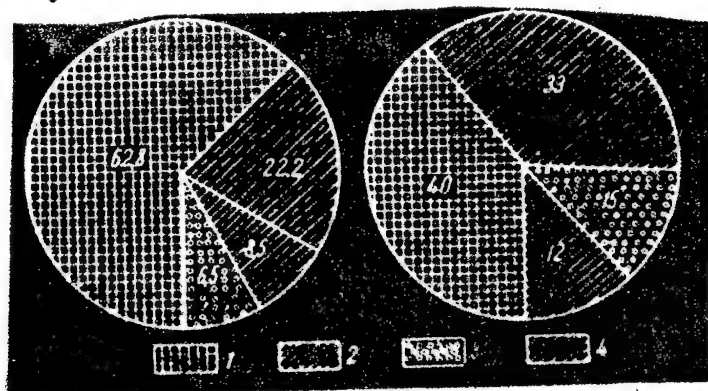


Fig. 3. Changes in the Proven Reserves of Lead (in percent)  
 1. Deposits of pyritic type; 2. In carbonate rocks; 3. In skarns; 4. Miscellaneous lead-zinc deposits

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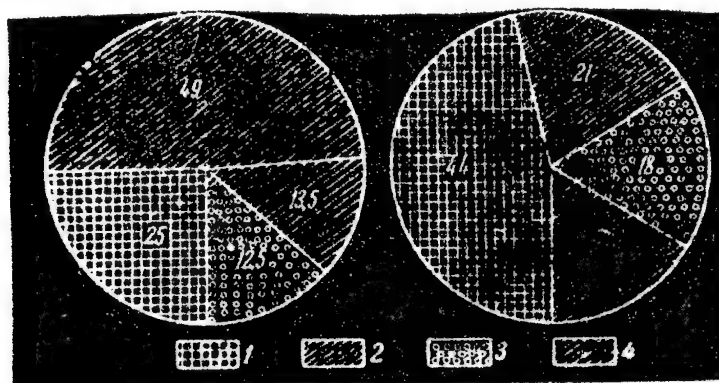


Fig. 4. Changes in the Extraction of Lead (in percent)  
 1. From lead-zinc deposits of the pyritic type; 2. From carbonate rocks; 3. From deposits in skarns; 4. From miscellaneous deposits

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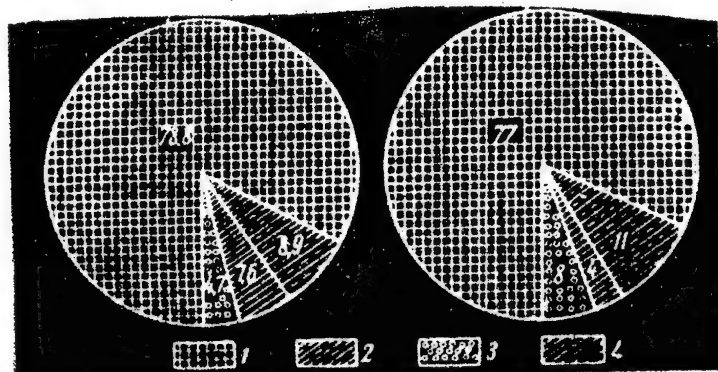


Fig. 5. Changes in the Proven Reserves of Zinc (in percent)  
 1. Lead-zinc deposits of pyritic type; 2. In carbonate rocks; 3. In skarns; 4. Miscellaneous types of lead-zinc deposits.

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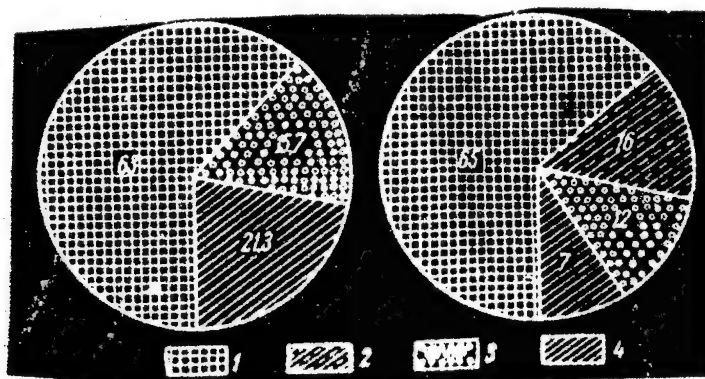


Fig. 6. Changes in the Extraction of Zinc (in percent)  
 1. From lead-zinc deposits of pyritic type; 2. From deposits in carbonate rocks; 3. From deposits in skarns; 4. From miscellaneous deposits.

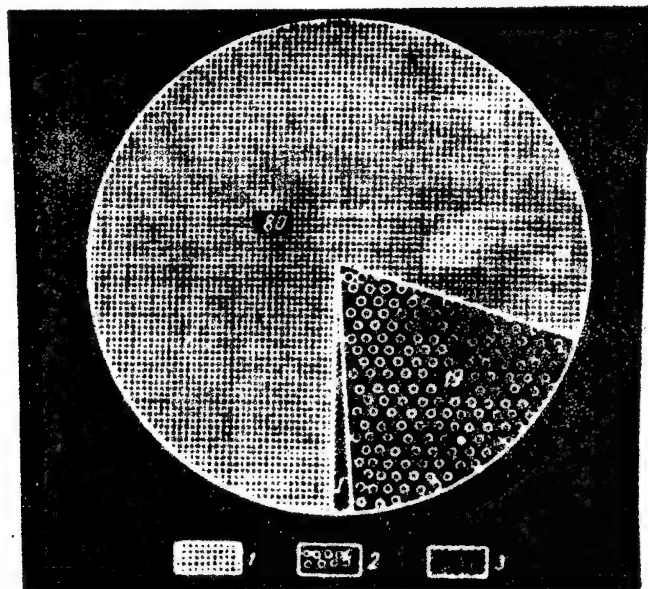


Fig. 7. Proven-Reserves of Tin in Various Types of Deposits as of 1 January 1957 (in percent)  
 1. In tin-sulfidic deposits; 2. In quartz veins; 3. In pegmatite bodies

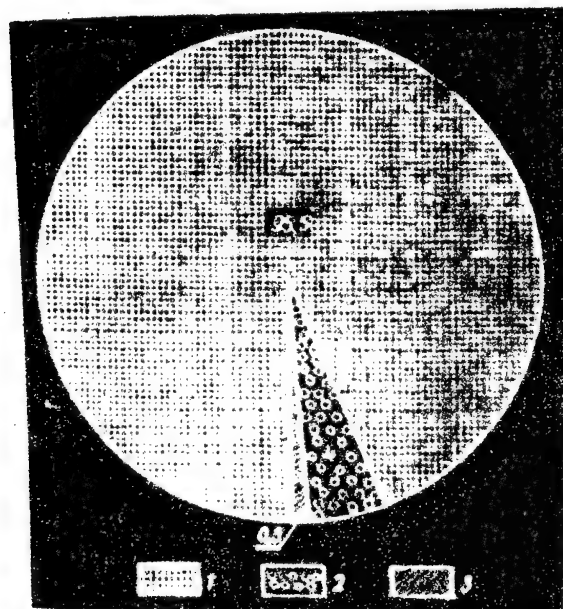


Fig. 8. Extraction of Tin as of 1 January 1957 (in percent)  
 1. From tin-sulfidic deposits; 2. From quartz veins; 3. From pegmatite bodies

## 7. Forty Years of the Ural Copper Industry

[This is a translation of an article written by M. G. Mironov, et al., in Byulleten' Tsvetnoy Metallurgii, No 19/20 (96-97), 1957, pages 55-60.]

Although the Ural copper industry dates from remote antiquity, the pre-Revolutionary copper-ore and copper-smelting industry was represented by small and technically poorly equipped enterprises. The majority of the copper deposits was exploited from shallow shafts and on a very limited scale. The technological level of the active ore mines was low, low-productive mining systems were employed, and steam installations predominated; there existed no conditions ensuring the safety of the conduct of mining operations, and the labor processes were mechanized only to an extremely small extent.

The smelting of copper ores was conducted in water-jacketed furnaces of a turn-of-the-century design. The Kalatinsk (now Kirovgrad) Plant, which in the pre-Revolutionary period was a "modern" enterprise, was activated only as late as in 1914.

During the period of World War I, despite the seemingly favorable market conjuncture in connection with the enormous demand for copper for military purposes, the smelting of copper had contrariwise decreased and, in view of the depletion of explored ore reserves, certain plants (Bogoslovskiy and Byyskiy in Sverdlovskaya Oblast) had been shut down. While in 1914 the Ural plants had smelted approximately 170,000 tons of copper, in 1917 they smelted only 10,000 tons.

During the period immediately following the Great October Socialist Revolution the situation of the copper industry was graphically described by Comrade Krzhizhanovskiy\*: "After the October Revolution the plants continued to operate for some time by force of inertia. Later their owners had vanished, and so did money. At the beginning of 1918 the plants finally closed down, and their workers scattered over the countryside. The State's representatives -- plant commissars and labor organizations -- had unsuccessfully tried to streamline their relations with the old plant administrations, and the necessity of transferring the plants to the ownership of the State became increasingly obvious. In October 1918 the plants became nationalized."

At the moment of nationalization all ore mines were

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\* "Works of the First All-Union Conference on Nonferrous Metals"

in a flooded state and plants were inactivated. Prior to their being shut down, the Kalatinsk, Pyshminskiy and Polevskiy plants had smelted altogether only about 850 tons of blister copper.

Thus, at the beginning of the Period of the Reconstruction of the National Economy the copper industry of the Urals consisted of several half-depleted and flooded mines and inactive partially demolished and obsolete small copper-smelting plants. The state of exploration of the deposits was extraordinarily low, and the long-term estimates of possible ore reserves were approximate and contradictory.

The workers of nonferrous metallurgy faced the following tasks:

- (1) Reconstruction of copper mines and of those copper smelting plants which had retained their technological equipment and could be reactivated in the shortest possible time;

- (2) Consolidation and further expansion of the ore base of the existing enterprises;

- (3) Investigation, exploration and preparation for exploitation of the then known but unworked deposits (Krasnogvardeyskiy, Novolevinskiy and Degtyarsk), for the purpose of establishing new copper-smelting plants on their basis.

The workers, engineers and technicians of the copper industry coped with these tasks honorably and within the shortest possible period.

In 1922 the renovated Severo-Karpushinskiy Ore Mine and the Belorechenskiy Ore Mines, and in 1924 the Kalatinsk Ore Mine (Kirovgradskiy Rayon), were reconstructed and opened. In June 1925 the Pervomayskiy Ore Mine was readied for exploitation, and, at the end of that year, so was the Ore Mine imeni Voroshilov (Karabashskiy Rayon).

The first copper smelted from ores was obtained on 5 May 1955 at the reconstructed Kalatinsk Plant -- now Kirovgrad Plant.

In 1925 the Karabash Copper Smelting Plant was opened and the Zyuzel'skiy Ore Mine, Polevskoy Copper-Smelting Plant and, in the Bashkirskaya ASSR, the Tanalyk-Baymakskiy Plant with its local copper mines, were reconstructed and activated. Also, the construction of the Krasnoural'sk Copper Smelting Plant began.

The establishment of that plant -- the first to have up-to-date facilities for ore processing (concentration, reverberatory smelting) -- constituted a new stage in the development of the Ural copper industry.

The First Five-Year Plan presented the copper industry with new and broader tasks, whose completion required radical changes in the technology of production. Despite the



extensive work conducted during the Reconstruction Period, both the mining and the metallurgical sectors of the copper-smelting industry remained on a rather low technological level.

Mining was based on archaic extraction systems and obsolete and low-productive machinery. Metallurgy was based on the method of the direct smelting of high-sulfur, zinc-bearing copper ores in water-jacketed furnaces, with total loss of sulfur and zinc. Impregnated copper ores were not being utilized. A radical modernization of the enterprises was necessary so as to raise their technological level and to perfect their techniques. It was necessary to build new enterprises equipped with the most up-to-date facilities.

The modernization was extended to all production sectors of the copper-smelting industry.

In mining, new and more efficient extraction systems were introduced, the labor-consuming processes were broadly mechanized, and the basic and auxiliary operations were electrified. In the field of the processing of polymetal ores the primary task to be solved was the introduction of flotational concentration -- a more perfect method than direct smelting, and one making it possible to utilize not only high-grade pyrites but also the low-grade impregnated ores, and to recover in addition to copper, gold and silver, sulfur and zinc as well.

At the Kalatinsk (Kirovgrad) Plant a concentrator shop was built for processing copper-zinc and impregnated ores. To smelt copper concentrates, a reverberatory furnace was activated at that plant in 1931. The mining economy of that region was expanded by the modernization of the Kalatinsk, Obnovlennyy and Severo-Karpushinskiy ore mines and by the construction of a new ore mine -- Levikhinskiy IX.

A new copper region was organized in Krasnoural'skiy Rayon. On the basis of new copper mines -- Krasnogvardeyskiy (1928) and Lovolevinskiy (1929), a giant enterprise including a concentrator plant (1930) and a copper-smelting plant with roasting and reverberatory furnaces (1931) was built.

The presence of a roasting shop at the Krasnoural'sk Plant made it possible, for the first time in the USSR, to materialize combined copper-smelting and sulfuric-acid-production operations. That plant was the first to apply electro-filters for collecting dusts from the gases of roasting furnaces and converters, and a band machine for pouring blister copper.

In the region of the Pyshma ore mines a pilot concentrator plant was built in 1931 and, after the reconstruction of these mines, adapted for the flotation of the copper ores of that region.

The introduction of the flotation method had also resulted in altering somewhat the orientation of geologic prospecting and exploring work. While during the Reconstruction Period the attention of geological organizations was turned to the prospecting for and exploration of pyritic ores to ensure the operations of water-jacketed furnaces, in 1927-1928 it was devoted to the prospecting for impregnated pyritic ores and ores of other genetic types. As a result, during the First Five-Year Plan the proven reserves of copper were considerably expanded and, additionally, the raw material base of the zinc industry was determined.

The ore balance was complemented with reserves of impregnated ores; reserves of copper ores were discovered in the Tur'ya ore mines, which had previously been regarded as depleted. The sizable increment in reserves had not only strengthened the ore base of the Kalatinsk (now Kirovgrad) Plant but also created the necessary premises for the further development of metal smelting.

During the Second and Third Five-Year Plans the work on modernization and new construction was continued. In the Tur'ya Ore Mining Region the Frolovskiy Mine was reconstructed re-equipped and reactivated in 1934; in the region of the Ore Mine imeni Third International new enterprises -- Mine imeni 15th Anniversary of the October Revolution (1934) and Ol'khovskiy Mine (1937) -- were equipped and opened; in the Kirovgradskiy Rayon the Levikha XII Mine was activated in 1933; and the Pyshma Mine was reconstructed and re-equipped in 1936.

In 1934 the largest copper electrolysis plant in the USSR and Europe was opened in Pyshma. It was to become the central copper-refining plant, thus processing blister copper from all copper-smelting plants. Therefore, the scale of its shops, with regard to both output capacity and size of furnaces and assemblies, had already at that time greatly surpassed the scale of the other domestic plants of this type.

Its technological scheme provided for the charging of copper into furnaces by special charging cranes. The heat of the furnace waste gases was utilized under boilers. "Carrousel" machines with a radial distribution of molds were used for pouring wire bars. The slimes of electrolytic production were retreated so as to recover gold, silver, selenium, and tellurium. The production of copper sulfate and copper powder was provided for.

In 1938 the first battery of the new Sredneuralsk concentrator shop was activated; in 1940 the Sredneuralsk Plant itself was opened, paving the way for the comprehensive recovery of the principle components from the copper-zinc ores of the Urals' largest Degt'yarsk Deposit. The design of

the Sredneural'sk Plant, drafted by the Unipromed' Copper Industry Institute, provided for a concentrator shop with a scheme of selective flotation into copper and pyrite concentrates (subsequently, after the perfecting of the scheme, into zinc concentrate also), and also for a copper-smelter including, among others, a roasting shop and a sulfuric acid works.

The outbreak of the Great War for the Homeland prevented the complete mastering of the above-outlined scheme, but this is being resumed now.

The plant is now equipped with huge metallurgical assemblies -- reverberatory furnaces with an eight-meter vault span and converters holding 90 tons of copper.

The new Blyava Ore Mine has served as the basis for constructing the Mednogorsk Copper-Sulfur Plant, which employs the direct smelting of copper ores in water-jacketed furnaces so as to obtain copper and elementary sulfur. The briquetting shop envisaged in the technological scheme has made it possible to retreat ore fines, which account for a rather high share of the yield of the Blyava Mine.

During the pre-war five-year periods the Ural copper industry had attained considerable successes in all of its sectors. As a result of extensive prospecting and exploring activities on the eastern slope of the Urals, within the confines of the Sverdlovskaya and Chelyabinskaya oblasts and Bashkirskaya ASSR, the proven reserves of copper ores were multiplied several times over.

In the field of the mining industry, old ore mines had been modernized and new and modernly equipped ore-mining enterprises had been constructed. The pre-Revolutionary indexes of the extraction of copper and sulfur ores were surpassed as in the First Five-Year Plan.

The mechanization of labor-consuming processes was raised to a high level. Thus, underground haulage was mechanized 71.4 percent, loading into railroad cars (inclusive of bunker shop) -- 93.0 percent, and so forth.

Major changes had also occurred in the systems of the mining of copper deposits. In 1913 and during the Reconstruction Period the mining of ores in the Urals was conducted by "extraction with timbering and flushing." In 1949 the distribution of extraction according to the mining system was as follows in the Urals (in percent):

Layer caving	36.9
Sublevel caving	8.1
With timbering and flushing	15.1
With flushing without timbering	11.9

With storing and the system of open chambers with extraction of ore from sublevel drifts	27.5
Open-strip extraction with square-set timbering	0.5

As a result of the application of more productive mining systems, labor productivity had also increased.

That period was marked by considerable changes in the technological methods of ore processing. While in 1913 and during the Reconstruction Period all ore extracted from the Ural mines was processed in conventional water-jacketed furnaces, in 1941 only 20 percent of the ore was smelted in these furnaces while the remaining 80 percent was entirely processed in concentrator plants. This has also served to increase the degree of utilization of the raw material through the additional recovery of sulfur and zinc therefrom.

The copper-smelting plants, processing basically the copper concentrates of their concentrator shops, had increased their productivity steeply. The pre-Revolutionary extent of copper smelting was surpassed as early as during the First Five-Year Plan.

In the postwar years the Ural copper industry has been developing at a rapid pace; however, the growing needs of the national economy for copper have required a still greater rise in the smelting of that metal.

During that period, radical changes have occurred in the ore-mining industry. Upon the appearance of domestic-produced high-productivity excavators and large 10- and 25-ton self-dumpers, it became possible to reexamine completely the problem of employing open-strip mining operations in the copper-ore industry; these operations ensure a high productivity of enterprises, exclude the likelihood of pyrite fires, reduce the losses of minerals, drastically improve the working conditions of miners, and assure the lowest possible extraction costs.

In 1955 approximately 40 percent of all copper ores extracted in the Ural deposits was extracted by open-strip methods. Open-strip methods are used to develop new deposits and in certain existing cupro-pyritic ore mines which had previously been designed for mining by the underground method, such as, e. g., the Blyava Mine, which began to be mined by open-strip methods in 1953.

In the field of underground mining the postwar period has been characterized by further improvements in the mining systems and the mechanization and automation of production processes.

The specific nature of pyritic ores with high sulfur

content has resulted in their spontaneous combustion and in inevitable fires; to combat these, the workers of the copper-ore industry had created a special field of mining science.

The silting-up of burning sectors by means of devices for conveying clay pulp to these sectors, "clay plants," has become a characteristic feature of every pyrite mine.

At present, the nature of fires and, especially, fire-combatting methods, have been sufficiently investigated and fire prevention is becoming a customary process in mining operations.

Flushing operations in the mines used to be a quite laborious business. The manual methods of conducting these operations had long delayed the exploitation of various sectors and even entire levels. At present, through the introduction of hydraulic flushing, this part of mining work has been perfected, and it appears that the further stages in the development of flushing operations will be oriented not so much toward accelerating the flushing process as toward searching for types of flushing material that would be cheap, convenient and capable of cementing and transforming itself into a monolithic material after a definite time interval.

The perfecting of mining systems has been oriented toward a proper selection of the most efficient of these systems as relating to the mining-technical conditions of various given deposits. The system of sublevel caving, with sublevels of a height increased to 15-20 meters, has lately been broadly applied for the impregnated and pyritic ores in which the fire hazard is non-existent or only slightly probable. This has increased the intensiveness of mining.

Under the same conditions, but under changed mining-technical circumstances (e. g., the thinner sectors of the Degtyarsk Deposit), another recently applied system was that of layer caving, with layers of a height of up to three meters, which has made it possible to increase labor productivity considerably.

In the deposits with proclivity for spontaneous combustion (30 to 40 meters thick), the newly applied systems involve layer caving combined with preventive measures consisting in the periodic conduct of silting-up operations.

Interesting activities have been conducted in certain sectors of the Mine imeni Thirs International with regard to the propping of mine passages, e. g., the propping of levels with cast slag stones. The slags of blast-furnace smelting are used for producing such stones. Observations of the state of the supports under the conditions of exfoliating rocks at that mine have yielded very satisfactory results. Obviously, upon a commensurate organization of labor, such



propping will be completely reliable and broadly applicable. Propping with bolts and with precast reinforced concrete is also being successfully introduced.

To convey ore, the copper mines have begun to use a new remote-control portable three-drum scraper winch developed by Unipromed' Institute.

The drilling of boreholes is being improved by the introduction of domestically-produced drilling machines with retractable pneumatic drills, which make it possible to drill holes measuring 160 and more millimeters in diameter and 30 to 40 meters in depth, thereby solving, in a number of cases, to solve in a novel manner the problem of the systems of operations and their parameters. These machines can also be for shaping the camber of quarries at open-strip mining work.

In the field of concentration of ore the postwar years have been marked by a search for new technological schemes for the purpose of a comprehensive utilization of raw materials. In certain concentrator plants the existing flotation schemes are being re-examined. Thus, at the Kirovgrad Concentrator Plant, in connection with its transition to the selective flotation of Levikhinskiye impregnates, the technological scheme provides for obtaining bulk concentrate, regrinding it in a newly installed grinding mill operating in a closed cycle with a spiral classifier, and the selective separation of that bulk concentrate so as to isolate copper, copper-zinc and pyrite concentrates. Despite the low content of copper, zinc and sulfur in the Levikhinskiye impregnates, the Kirovgrad Concentrator Plant recovers a great amount of copper into concentrate, and its indexes of the recovery of sulfur and zinc are sufficiently satisfactory. To ensure normal operations of the crushing department at that plant, the raw-ore bunkers have been modernized. The discharging orifices of the bunkers have been greatly enlarged and heavy-type plate feeders have been installed.

The Krasnoural'sk Concentrator has a scheme for processing the copper-zinc ores of the Mine imeni Third International for the purpose of increasing selectivity and the recovery of metals into concentrates. The new scheme provides for a staged copper flotation followed by two control flotations. The tailings of the copper flotation proceed toward bulk flotation, thus yielding a zinc-pyrite bulk concentrate and quartz tailings which are used at the plant as fluxes. The zinc-pyrite concentrate proceeds toward zinc flotation, which yields a zinc concentrate after triple dressing and pyrite concentrates (tailings of zinc flotation).



The indexes of flotation of the ores of the Mine imeni Third International (for 1955) are cited in Table 1.

Table 1

Product	Content in percent			Recovery in percent		
	Cu	Zn	S	Cu	Zn	S
Ore.....	1.8	5.2	20.4	---	---	---
Copper Concentrate..	13.15	9.03	38.7	87.9	20	22
Zinc Concentrate....	1.17	51.23	34.3	4.5	69.5	11
Pyrite Concentrate..	0.37	0.96	38.7	5.7	5.0	49.5
Quartz Tailings.....	0.1	0.53	5.7	1.9	5.5	17.5

The Pyshma Concentrator Plant had been processing for nearly 10 years the ores of the Pyshma Deposit, so as to isolate only the copper concentrate. Later, that plant was expanded and converted to selective flotation with isolation of copper and pyrite concentrates. The scheme of its flotation is: bulk flotation of sulfides, followed by regrinding of bulk concentrate and isolation therefrom of copper and pyrite concentrates. Table 2 cites the indexes of the processing of Pyshma ore in 1954.

Table 2

Product	Content in percent		Recovery in percent	
	Cu	S	Cu	S
Ore.....	0.59	3.43	---	---
Copper Concentrate...	28.58	32.82	92	19.08
Pyrite Concentrate...	0.33	43.8	3.73	77.8
Refuse Tailings.....	0.02	0.11	4.27	3.12

The operating indexes of the Pyshma Plant appear to be sufficiently high with regard to both the quality of concentrates and the recovery.

The Karabash Concentrator Plant has converted to the selective flotation of the local copper-zinc ores. Its flotation scheme is more complex than in other concentrator plants; however, its technological indexes lie on a sufficiently high

level (Table 3, data for 1956).

Table 3

Product	Content in percent			Recovery in percent		
	Cu	Zn	S	Cu	Zn	S
Ore.....	2.03	2.03	--	--	--	--
Copper Concentrate...	13.63	--	--	88.95	--	--
Zinc Concentrate.....	3.0	49.44	--	3.0	52.6	--
Tailings.....	0.16	0.48	--	7.05	--	--

While converting to selective flotation the Ural concentrator plants have also been working on the utilization of the valuable components in the tailings.

The Sredneural'sk and Krasnoural'sk concentrators have provided the chemical industry with over two million tons of pyrite tailings from their tailing dumps. The Pyshma concentrator has been processing since 1942 all of its previously dumped tailings in a temporary structure built on the dumping yard, thus obtaining valuable pyrite concentrate.

In the field of metallurgical production the postwar period has been marked by intensified searches for ways and means of the fullest and most efficient utilization of the valuable components of the processed raw material. To increase the recovery of zinc, Unipromed' Institute and the Kirovgrad Plant had developed a new technological process for the comprehensive retreatment of copper-zinc concentrates -- the process of pyrometallurgical zinc selection, which makes it possible to carry out the separation of the copper-zinc products obtained as a result of the processing of the polymetal ores which are not subject to satisfactory selection during concentration. The first industrial installation operating according to this method has been designed and built at the Kirovgrad Plant, and is now in operation there.

The conducted researches and economic calculations have provided a foundation for assuming that the following may be the most applicable methods of processing copper-zinc concentrates.

In the case a plant processes chiefly a cupriferous raw material which is accompanied by a small amount of copper-zinc complex raw material, the best method of processing the latter is the pyro-selective method.

On the other hand, in the case a plant processes

exclusively the copper-zinc raw material, it is more expedient to provide for a higher degree of roasting of the charge and for smelting the charge in reverberatory furnaces into high-zinc slags, to be followed by the fuming of these slags so as to recover zinc in the form of an oxide.

In connection with the construction of a roasting shop at the SUMZ [Sredneural'sk Copper Smelting Plant], that plant is provided with the possibility of a successful introduction of the process of the fuming of reverberatory-furnace slags. At present, a fuming installation is being designed there. An analogous installation is being designed at the Krasnoural'sk Copper Smelting Plant.

The geological prospecting for new raw material resources has resulted in a continual increase in the share of copper-zinc ores and a decrease in the share of copper ores. This provides a foundation for expecting a further increase in the quantities of the copper-zinc material received for processing by the Ural copper smelting plants.

The research and design work pertaining to the employment of fluidized-bed roasting of the charge of reverberatory furnaces has been considerably expanded. This method of roasting makes it possible to obtain a richer (containing up to 12 percent  $\text{SO}_2$ ) by-product gas than does the method of roasting in furnaces with mechanical rabbling of the roasted charge (up to seven percent  $\text{SO}_2$ ), currently employed at Krasnoural'sk. In this connection, it may be feasible to utilize, in sulfuric-acid plants, converter gases having a low content of sulfur dioxide, because the mixture of the gases of converter and roasting shops will be sufficiently rich for inclusion within the sulfuric-acid production system. At present the Sredneural'sk Plant is working on the construction of a shop for fluidized-bed roasting and a sulfuric-acid production nexus.

In addition, the Sredneural'sk Plant is modernizing its charge-preparing operations and constructing the necessary facilities for the reception of raw materials, thereby incorporating all the modern innovations in this field. Special attention has been devoted to organizing the reception and assaying of gold-bearing fluxes. A modern charge-blending machine built by the Yuzhnoural'sk Machine Building Plant has been installed in the mixing shed. To improve the hygiene of labor in the flux-crushing department, the wet crushing of quartz and limestone has been adopted so as to avoid the pollution of air with dust harmful to the health of the servicing personnel.

The continuous increase in the smelting of blister copper and the widespread use of gold-bearing fluxes have

increased steeply the yield of slimes containing precious and rare metals. The growing demand for rare metals has stimulated the initiation of research in the field of methods of retreating slimes that would make it possible to increase greatly the recovery of selenium and tellurium. The results of this research have served as the basis for the designing and start of the construction of a new slime shop at the Pyshma Copper Electrolysis Plant, with an output capacity to be much greater than that of the present shop. The labor-consuming processes in that shop will be mechanized and automated to the maximum extent.

Scientific-research work has also been conducted with regard to investigating the conditions of the concentration of rare elements in the dusts of metallurgical assemblies and the methods of recovering them.

As a result, it was found possible to commence the construction of installations for recovering rare metals from dusts at the Mednogorsk and Kirovgrad plants.

The mastering of a new special type of production needed by the national economy has been commenced. The Kyshtym Copper Electrolysis Plant is building a pilot installation for the electrolytic obtainment of high-grade copper foil. Samples of this new type of production have already been obtained on this installation.

Such, in brief, is the outline of the development of the Soviet copper industry in the Urals.

The present state of the level of output and technological equipping of that industry's enterprises simply are not comparable with their state in the pre-Revolutionary period. The technologically backward copper industry of the Urals, feeble as it was in every respect, has during the Soviet Era become transformed into a vigorous branch of economy with a pace-setting technology of production and highly advanced techniques.

## 8. Removal of Arsenic From Secondary Dust in the Novosibirsk Tin Plant

[This is a translation of an article written by V. S. Lovchikov, B. M. Lipshits, and A. P. Sorokina in *Tsvetnyye Metally* (Nonferrous Metals), No 8, Aug 59, pages 54-56.]

The secondary dust at the Novosibirsk Tin Plant contains 33.4 percent As; 4.0 percent Sn; 16.1 percent Fe; 11.78 percent  $\text{SiO}_2$ ; 1.82 percent Zn; 1.2 percent Pb; 0.76 percent Ca; 0.26 percent Cu; 0.25 percent Bi; 0.24 percent  $\text{TiO}_2$ ; 0.07 percent Cl; 0.05 percent Sb; and traces of  $\text{WO}_3$ . The arsenic in the dust is present principally in the form of trioxide.

It is inexpedient to introduce such a product into the smelting charge of tin-bearing materials in view of the high content of arsenic, and the presence of tin therein does not make it possible to exclude the dust from the scheme of the retreatment of tin concentrates. Hence, the necessity has arisen of developing a method of removing the arsenic from the dust, which would make it possible to return tin into the concentrate smelting charge and to obtain arsenic in the form of a marketable product.

The extraction of arsenic from dusts by distillation is a commonly accepted method. The realization of such a technology requires expensive dust-collection apparatus and a painstaking hermeticization of the gas conduit, because the permissible concentration of arsenic in the air within industrial premises amounts to not more than 0.0003 milligrams per liter (Bibl. 1). We have carried out a study of the extraction of arsenic from a dust with the afore-described composition by the hydrometallurgical method.

The Leaching of Arsenic From Dust. Arsenic trioxide is satisfactorily soluble in water (Bibl. 2), and therefore we investigated the conditions of the passing of arsenic into a solution by treating dust with water. The investigation concerned the effect of temperature, time and the L/S [Liquid-to-solid] ratio on the dust leaching process.

The effect of temperature was studied during the treatment of dust with water for 1.5 hours and at a L/S ratio of 10;1. The obtained data are cited in Fig. 1 from which it follows that the maximum amount of arsenic passes into the solution at 95 to 100°C.

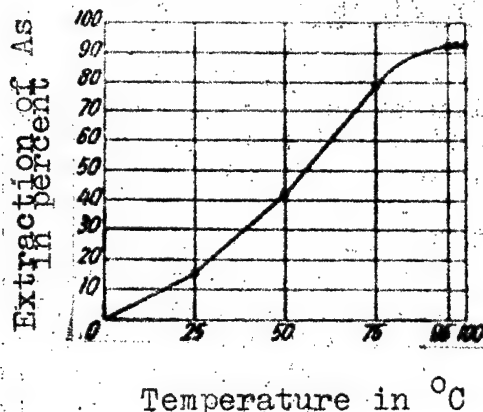


Fig. 1. Effect of Temperature on the Extraction of Arsenic into the Solution During Leaching With Water

The data on the study of the duration of leaching at 95°C and  $L/S = 10;1$  are presented in Fig. 2. The results of these experiments showed that, under the above-indicated conditions, 93 percent of the As is leached out within 30 minutes. A longer treatment of dust with water increases the recovery of arsenic into the solution to an insignificant degree only. The presence of arsenic in the insoluble residue is apparently to be explained by the presence in the dust of small amounts of the compounds of arsenic with iron, which are insoluble in water.

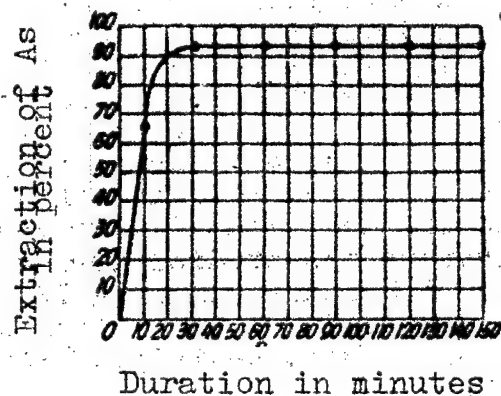


Fig. 2. Relationship Between the Extraction of Arsenic at its Leaching and the Duration of the Operation



Fig. 3. illustrates the effect of the L/S of the pulp on the extraction of arsenic into the solution. When  $L/S = 3.5 : 1$  and the temperature is  $95^{\circ}\text{C}$ , not more than 50 percent of the As is passed into the solution during 30 minutes; when  $L/S = 10.5 : 1$  the percentage of extracted As climbs to over 90 percent. Any further dilution of the pulp with water will increase the recovery of arsenic into the solution only to a nugatory degree. The then resulting solid residue contains: seven percent Sn; five percent As 27 percent Fe; and 20 percent  $\text{SiO}_2$ .

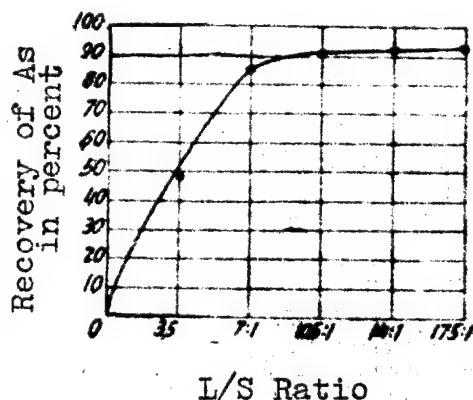


Fig. 3. Effect of L/S Ratio in Pulp on the Degree of Recovery of Arsenic

After the leaching of the dust no tin was found in the solution.

The Precipitation of Arsenic. Arsenic can be segregated from the solution in the form of various compounds. We precipitated it in the form of calcium arsenite with lime.

The mixing of the solution with a 10-percent excess of lime as compared with the theoretically necessary amount of lime for forming calcium arsenite is conducive, at  $95^{\circ}\text{C}$  and for the duration of 30 minutes, to the precipitation of over 95 percent of the As. The prolongation of this operation to three hours had virtually no effect on the completeness of the precipitation of arsenic.

Upon filtration of the pulp the calcium arsenite separates satisfactorily from the solution in the form of a white cake, which we washed with water and dried. The dried cake contained 47 percent As, which corresponds to 62 percent  $\text{As}_2\text{O}_3$ . Such a product satisfies the GOST [State Standard] requirements for calcium arsenite, and hence it is a marketable product which can be utilized as a

"yadokhimikat" [fungicide, pesticide, etc.] (Bibl. 3).

The filtrate separated from the calcium arsenite contains approximately 15 percent of the initial content of As in the solution. It is expedient to use the solution for treating new portions of the dust.

Scheme of Removing Arsenic From Dust. On the basis of the conducted investigations we recommend the scheme of removing arsenic from secondary dust, which is employed at the Novosibirsk Tin Plant (Fig. 4). It can be seen from this scheme that the recovery of arsenic from the dust in the form of calcium arsenite requires the use of altogether only two reagents, one being water and the other, lime. Moreover, the apparatus used in this process is not complex.

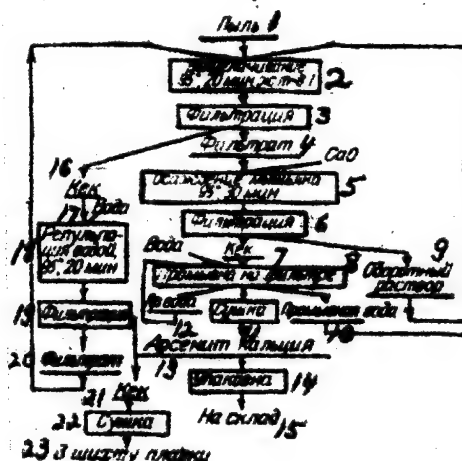


Fig. 4. Recommended Scheme of Cleaning the Secondary Dust of the Novosibirsk Tin Plant  
 1. Dust; 2. Leaching, 95°C, 20 minutes, L/S = 8:1; 3. Filtration; 4. Kiltrate; 5. Precipitation of arsenic, 95°C, 30 minutes; 6. Filtration; 7. Cake; 8. Washing in filter; 9. Reflux solution; 10. Washing water; 11. Drying; 12. [illegible] 13. Calcium arsenite; 14. Packaging; 15. To depot; 16. Cake; 17. Water; 18. Repulping with water, 95°C, 20 minutes; 19. Filtration; 20. Filtrate; 21. Cake; 22. Drying; 23. Into smelting charge

The simplicity of the recovery of arsenic from dust at the Novosibirsk Tin Plant indicates the expediency of examining the possibility of applying this technology to the dusts of the lead, zinc and copper-smelting plants.

### Conclusions

1. Arsenic is leached with water from the secondary dust of the Novosibirsk Tin Plant. At 95°C and L/S = 10:1 the stirring of the pulp for 30 minutes results in the passing of 93 percent of the As into the solution. Any further prolongation of the time of the treatment of the dust with water and any further increase of the L/S ratio raises the extraction of arsenic only to an insignificant degree. The solid residue of the leaching of the dust contains seven percent Sn, five percent As, 27 percent Fe and 20 percent SiO<sub>2</sub>.

2. Arsenic in the solution can be precipitated with lime in the form of calcium arsenite. At a 10-percent excess of lime over the theoretically necessary amount of lime, approximately 85 percent of the initial content of As in the solution becomes precipitated out within 30 minutes. The obtained calcium arsenite can, after washing and drying, be used as a pesticide.

3. The filtrate separated from calcium arsenite can be expediently utilized for leaching new portions of the dust, because it contains about 15 percent of the initial content of As in the solution.

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9. Certain Characteristics in the Technology of Processing  
Combined /Bulk/ Copper-Zinc Concentrates at the  
Sredneural'sk Copper Smelting Plant\*

[This is a translation of an article written by V. A. Aglitskiy, et al; in Tsvetnyye Metally, No 9, Sep 59, pages 38-45.]

(In the Order of Discussion)

The copper smelting plants of the Urals process cupro-pyritic ores of a complex composition. These ores contain, besides copper, considerable amounts of sulfur, iron, zinc, certain amounts of lead, cadmium and noble metals, and a number of rare and dispersed elements of extreme importance to the national economy. The relative value of the valuable components of these ores, not counting the rare elements, may be thus approximately represented: sulfur -- 53 percent; copper -- 26 percent; zinc -- 17 percent; and noble metals -- four percent.

During the processing of copper ores and concentrates at the Ural plants the recovery of zinc is approximately less than 30 percent, because only a part of the ores is subjected to selective flotation; the utilization of the sulfur of metallurgical gases is far from adequate, as its recovery from these gases amounts to approximately 21 percent, chiefly owing to the use of the roasting gases of the Krasnoural'sk Plant; all the iron is completely forfeited; and lastly the recovery of zinc and rare elements from the production dusts and slags has still not been organized as yet.

The principal causes of such an unsatisfactory situation regarding the utilization of the material composition of an extremely valuable ore raw material are the incompleteness of the metallurgical schemes applied in the Ural plants and the partial underconstruction of certain plants, e. g., the Sredneural'sk Plant.

During this seven-year period, for the purpose of liquidating the principal drawback in the performance of the Ural plants -- the limited comprehensiveness of the

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\*Reply to the article by L. M. Gazaryan on "Certain Characteristics of Modern Converting and a Rational Technology of Copper Smelting Plants of the Urals in the Seven-Year Plan," Tsvetnyye Metally, No 4, 1959

utilization of the raw material -- the plans provide for measures to raise steeply the recovery of zinc, sulfur and rare elements. For this purpose, in addition to a further improvement of the process of selective flotation, the plants intend to introduce improved dust-collection schemes and to ensure the maximal recovery of zinc, lead and rare elements from the metallurgical dusts and slags. There also exist plans for the fullest utilization of the sulfur of metallurgical gases, which, for the Urals as a whole (not counting the Mednogorsk Plant), should be increased to 70 percent in 1965 as compared with the currently existing 21 percent utilization.

The maximum development in this direction during the seven-year period should occur at the SUMZ [Sredneuralsk Copper Smelting Plant], which intends to organize the roasting of concentrates by the "fluidized-bed" method on utilizing the high-sulfur roasting gases together with the converter gases for the production of sulfuric acid, as well as other measures for recovering zinc and rare elements.

The realization of these measures at the SUMZ alone will make it possible to increase drastically the economic effectiveness of that plant by augmenting the smelting of copper one and one half to two times and ensuring a substantial additional income.

In connection with the foregoing we deem it necessary to dwell on L. M. Gazaryan's article on "Certain Characteristics of Modern Converting and A Rational Technology of Copper Smelting Plants of the Urals in the Seven-Year Plan." (Tsvetnyye Metally, No 4, 1959), in which he completely denies the expediency of the scheme of smelting concentrates with preliminary roasting and with the utilization of sulfur-bearing gases for the production of sulfuric acid, especially at the SUMZ.

Such a very simplified opinion on the processing of copper-zinc concentrates in Ural plants is, in our view, the result of the erroneous premises on which L. M. Gazaryan bases his considerations. First of all, let us examine his principal conclusion stating that in worldwide practice "the previously consolidated standard scheme (roasting-reverberatory smelting-converting) is becoming subject to changes, with gradual elimination of roasting...." The main error consists in that, in asseverating this, L. M. Gazaryan completely overlooks the actual situation and technical-economic conditions in which a number of plants in the United States operate according to that scheme.

Upon an analysis of the reasons for the employment of the smelting of raw (unroasted) concentrates under conditions

in the United States, it is impossible to disregard the specific conditions of the operation of the American copper smelting plants, which fundamentally can be reduced to the following.

1. The most characteristic feature of the operation of reverberatory furnaces in the copper smelting plants of the United States is their considerable reserve capacity and the high content of copper in the concentrates; therefore, the problems of furnace productivity in the United States are of a secondary importance as distinguished from e. g., Canadian practice.

The content of copper in the mattes of these plants ranges from 32 to 40 percent, despite the absence of roasting.

During the present Seven-Year Plan the Krasnoural'sk and Sredneuralsk plants will operate at maximum capacity; therefore, the increase in the productivity of their reverberatory furnaces acquires importance.

2. A majority of the American reverberatory furnaces operates on natural gas, i. e., on a cheap fuel, which also is beneficial to smelting the raw charge.

In Canadian practice, on the other hand, the output capacities of the plants are limited, the copper content of the concentrate is comparatively low (10 to 15 percent), and imported fuel constitutes a major expenditure item. As a rule, in the reverberatory furnaces, the charge is smelted in roasted form with an extremely high smelting rate. For instance, at the Noranda Plant the smelting rate amounts to 7.8 tons per square meter of furnace hearth daily.

3. Lastly, the American plants usually smelt high-grade pure copper concentrates containing virtually no zinc, which also makes it possible to obtain sufficiently high operating indexes even when smelting unroasted charge. Therefore, the special technological schemes used for processing a complex raw material are used there in exceptional cases only. On the other hand, the Canadian Flin-Flon Plant processes its complex zinc-containing concentrates on the basis of a scheme that is practically fully analogous to the one designed for the SUMZ.

Furthermore, let us point out that Stevens, while carrying out a special technical-economic analysis comparing the costs of processing concentrates in the raw and roasted forms, respectively, as applied to conditions in the United States and Canada, arrived at the conclusion that "as a rule it can be assumed that if the smelting of raw charge yields a matte containing less than 20 percent of copper, then roasting is necessary."

In his attempt to prove the advantages of smelting raw



copper-poor concentrates in the reverberatory furnaces under conditions of the Ural plants, L. M. Gazaryan cited data on the costs of metallurgical reduction in Ural plants which do not entirely coincide with the accounting data of these plants for the last few years, as can be seen from Table 1.

Table 1

Costs of Metallurgical Processing at the Krasnoural'sk and Sredneural'sk Copper Smelting Plants per Ton of Blister Copper, in Rubles

Items of Expenditure on Metallurgical Process	1956		1957		1958	
	KUMZ	SUMZ	KUMZ	SUMZ	KUMZ	SUMZ
Fluxes.....	112.01	58.82	119.19	50.07	120.13	44.64
Fuel.....	226.58	404.34	203.64	401.77	210.01	335.89
Power Consumption	80.31	96.94	73.92	89.81	83.11	81.01
Total Wages and Benefits.....	159.10	107.38	158.20	121.40	158.84	114.13
Shop Expenses....	327.80	399.88	324.35	365.74	338.04	366.31
Total Costs of Metallurgical Processing.....	905.80	1067.36	879.20	1028.07	910.13	941.88
Returns from Sulfur (—)...	363.64	--	391.45	--	405.20	--
Costs of Processing per Ton of Blister Copper*	542.16	1067.36	487.75	1028.07	504.93	941.88

\*Here the returns from steam, which are somewhat greater when smelting raw charge, are not considered.

This table shows that the total costs of the metallurgical processing of blister copper at the Krasnoural'sk Plant, i. e., for the scheme with roasting, are approximately 10 percent lower than at the Sredneural'sk Plant, where raw charge is smelted.

If, however, we take into account the utilization of sulfur, i. e., a higher complexity of the scheme with roasting which L. M. Gazaryan had silently disregarded, then the processing costs at the Krasnoural'sk Plant will be found to be a half as low as at the Sredneural'sk. Furthermore, the

statement that the charge used at the Krasnoural'sk Plant is richer than that used at the Sredneural'sk Plant is untrue, as can be seen from the data in Table 2.

Table 2

Principal Operating Indexes of Ural Plants

Index	1955	1958	1955	1958
	Sredneural'sk		Krasnoural'sk	
Copper Content of Charge, in percent.....	9.3	9.2	8.8	7.3
Copper Content in Dumped Slag, in percent.....	0.45	0.44	0.41	0.38
Consumption of Nominal Fuel, for Reverberatory Smelting, in percent of Solid Charge	22.8	22.1	14.9	14.1
Recovery of Copper, in percent	92.1	92.4	91.9	92.8
Smelting Rate, in tons per square meter daily.....	4.6	5.0	6.2	7.3

Thus, the thesis of L. M. Gazaryan that "the exclusion of roasting from the technological cycle does not raise the shop costs of metallurgical processing" is not justified for the Ural plants.

It is likewise impossible to agree with his other postulate that "the converter process is much cheaper than the reverberatory one." First of all, in principle, it is incorrect to compare these processes according to the cost of the oxidation of sulfur alone. While the converter actually executes totally different functions -- the smelting of charge and the formation of slag and matte, and also the separation of these phases and the purification of converter slags. Desulfating during reverberatory smelting is basically determined by the composition of the charge -- by the presence of solid oxygen and higher sulfides in the charge, and least of all by the actual process of performance of the furnace. Therefore, the data cited by L. M. Gazaryan concerning the costs of the oxidation of sulfur in the converter and in the reverberatory furnace are not comparable; nor need we cite the fact that -- even according to these data -- roasting, and not bessemerizing, is the cheapest operation in the oxidation of sulfur.

Although we are in complete accord with L. M. Gazaryan's opinion on the desirability of a maximum increase in the content of silica in converter slags, we cannot agree with his comment on the expediency of obtaining "mattes as lean as possible in a given plant."

As is known, converter slags are a returnable product and their reprocessing in the reverberatory furnace, especially in large amounts (i. e., in the case of lean mattes) involves considerable difficulties. Thus, in the conditions of the Sredneuralsk Plant, in the case of mattes containing 14 to 17 percent of Cu, there is obtained so great an amount of converter slags that the reverberatory furnace is not able to receive them in molten form. Throughout 1958 the reverberatory furnace at the SUMZ was able to receive only about 50 percent of the molten converter slags. The other 50 percent was charged into the furnace in the chilled form, which was reflected in a rise in processing costs because of the expenditures on the crushing and transporting of the chilled slag and the additional consumption of fuel for re-smelting that slag. On the other hand, an increase in the copper content of matte (so as to reduce the amount of converter slags) at the SUMZ, where raw charge is smelted, could not be feasible without roasting.

Lastly, it is necessary to dwell on the question of utilizing gold-bearing fluxes in the smelting of concentrates. The total amount of fluxes necessary for forming a slag of a given composition during smelting does not, as is known, depend on the scheme of the processing of concentrates (with or without roasting) but is determined by the composition of the concentrate (the presence of iron therein).

However, here L. M. Gazaryan deems it most expedient to utilize maximally the gold-bearing fluxes in the converter, which, as applied to the Ural conditions, cannot be agreed with.

The current partial utilization by the Ural plants of ordinary (nonauriferous) quartz fluxes is attributable not to the specific features of the technology of these plants but to the considerable shortage of converter-grade fluxes. The extraction and processing of gold-bearing fluxes from the Ural deposits usually yield an excess of fluxes of the reverberatory-furnace grade, so that, in the Urals, it is necessary primarily to find applications for this grade and not for the converter grade. Also, it should be considered that the requirements for the quality of fluxes of the reverberatory-furnace grade are somewhat lower than those for fluxes of the converter grade (Table 3), and not conversely as is asserted by L. M. Gazaryan, i. e., that the maximal

utilization of fluxes of the reverberatory-furnace grade makes it possible to utilize more broadly the deposits of gold-bearing quartzes.

Table 3

Requirements for Quartz Fluxes

Grade	Size in millimeters	(Minimal) Content of $\text{SiO}_2$ in percent	(Maximal) Content of $\text{Al}_2\text{O}_3$ in percent
Converter.....	from 8 to 30	65.0	9.0
Reverberatory-Furnace.....	" 0 " 8	60.0	12.0

Thus, from the standpoint of a greater utilization of gold-bearing fluxes in the Urals, it is likewise more expedient to smelt roasted charge. Then the total recovery of noble metals, as based on a suitable preparation of the charge, should be not lower but rather higher than when raw concentrates are smelted.

L. M. Gazaryan's assertion that the Ural plants currently operate at considerable reserve capacity does not correspond with reality. The operating reverberatory furnaces of the principal Ural plants -- Krasnoural'sk and Sredneural'sk -- work at full capacity, as can be seen from their rate of productivity (see Table 2). The simultaneous operation of secondary furnaces at these plants -- under existing conditions -- is virtually impossible, because this would require the expansion of the dust-collecting shops and converter departments, the modernization of charge-preparing and slag-conveying facilities, and certain additional measures; moreover, at the Krasnoural'sk Plant it would require an expansion of the roasting shop. In other words, such reserve output capacities could be created only after a commensurate expansion and modernization of these plants, which under present conditions is not yet feasible.

In his attempts to justify the inexpediency and even harmfulness of roasting in the processing of copper-zinc concentrates, L. M. Gazaryan, on arbitrarily touching upon the practice of the Canadian Flin-Flon Plant, maintains that deep roasting merely deteriorates the conditions of the retreatment of high-zincous concentrates in the reverberatory furnace.

The operating practice of the Sredneural'sk Plant in its processing of zincous concentrates has shown that the smelting of concentrates containing over seven percent of zinc evolves with great difficulties. In such a case, no appropriate separation of smelting products occurs in the reverberatory furnace; an intermediate zincous layer forms, the losses of copper in dumped slags increase, the tapping of the smelting products from the furnace becomes greatly complicated, and so forth.

As early as in 1935 a research project including a series of laboratory smeltings of copper-zinc concentrates with various degrees of roasting was conducted at the Uralgintsvetmet [Ural State Scientific Research Institute of Nonferrous Metals], under the guidance of Professor V. I. Smirnov. This demonstrated that the normal separation of smelting products is observed only in rich mattes, i. e., after the deep roasting of concentrates. A number of subsequent projects executed by researchers of Unipromed' Institute -- both under laboratory conditions and jointly with the workers of the SUMZ -- on the experimental furnace of that plant has made it possible to investigate circumstantially and to establish the principal technological parameters of the smelting of roasted copper-zinc concentrates yielding rich mattes and zincous slags.

Inasmuch as during the Seven-Year Period the concentrates arriving at the Sredneural'skiy Plant will, on the average, contain over eight or nine percent of zinc, therefore their processing without a commensurate roasting would be virtually infeasible. The correctness of this viewpoint raises no doubts whatsoever among the workers of the Ural copper-smelting industry.

A characteristic feature of the smelting of deep-roasted copper-zinc concentrates is the absence of the formation of zincous and ferritic "sows" on the furnace hearth bottom. The cause of these phenomena has been investigated previously.\* Here it is necessary to dwell once more on the difficulties that have arisen at the Flin-Flon Plant in connection with the formation of ferritic "sows" during the initial period of the mastering of the smelting of copper-zinc charge. There, in effect, one of the measures conducive to normalizing the operations was a certain reduction in the degree of roasting of the concentrates, which had, however, resulted in obtaining mattes containing 24 to 26 percent Cu compared with seven to

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\*Tsvetnyye Metally, No 2, page 29, 1957

eight percent Cu in the charge. In other words, even then a high degree of roasting was still retained.

The above-mentioned reduction in the degree of roasting at the Flin-Flon Plant is completely valid, if one considers that a zinc content of up to 8.5-9 percent in dumped slags is achieved by retreating together with the furnace charge the tailings consisting chiefly of zinc ferrites (except for the ferrites contained in the charge roasted in multiple-hearth furnaces). Clearly, it is desirable under these conditions that the roasted charge contain a greater amount of the sulfur necessary for disintegrating both the ferrites contained in that charge and the ferrites introduced in the tailings from the concentrator plants. The charge roasted in a fluidized bed contains only one or two percent of hematite, and the principal products of roasting are magnetite and "vyustit" [?]. Consequently, the operating conditions of the Flin-Flon Plant differ considerably from the conditions taking place during the smelting of roasted concentrates obtained in fluidized-bed furnaces. In the latter case the conditions will be particularly favorable for the smelting of the charge yielded by the roasting of concentrates in the granulated form as adopted in the SUMZ project.

Let us now consider the problem of the utilization of the principal component of the Ural cupro-pyritic ores -- sulfur, whose value, as noted previously, accounts for over 50 percent of the value of principal components of these ores.

The distribution of sulfur in the gases of the metallurgical assemblies of copper-smelting plants according to 1954 data is cited in Table 4.

Table 4

Distribution of Sulfur in Gases, in percent

Name of Gas	Plant	
	Krasnoural'sk	Sredneural'sk
Roasting Gases.....	66.0	61.5
Converter Gases.....	28.0	39.0
Reverberatory-Furnace Gases..	6.0	
Total.....	100.0	100.0



It can be seen from the data in Table 4 that, upon elimination of roasting, it is possible to utilize for sulfuric-acid production only about 60 percent at most of the S passing into the gases, whereas if roasting is included this figure climbs to 95 percent. The fundamental advantage of the utilization of gases for the scheme with roasting consists in that the bulk of the sulfur can be conveyed to sulfuric-acid production in the form of very sulfur-rich (containing up to 10 percent of sulfur dioxide) roasting gases, and that then the lean converter gases (containing four to four and one half percent of sulfurous anhydride) can be processed together with these roasting gases very successfully and with high technical- economic indexes.

When utilizing converter gases it is not feasible to transmit all of these gases to sulfuric-acid production, because the very conditions of the process cause part of them to escape, and because their content of sulfur dioxide will probably be no higher than four and one half percent in connection with the absorption through the dust screen, as anticipated in the project for utilizing converter gases at the Krasnoural'sk Plant.

Obviously, at such a content of sulfur dioxide in gases, all technological indexes of sulfuric-acid production will be steeply lowered, a fact which cannot be disregarded when operating with raw, unroasted charge. The relationship between the principal technical-economic indexes of sulfuric-acid production and the content of sulfur dioxide in sulfur-bearing gases according to data of the Giprokhim [State Institute for the Design and Planning of Chemical Industry] is shown in Table 5.

Table 5

Relationship Between the Technical-Economic Indexes of the Manufacture of Sulfuric Acid and the Content of  $SO_2$  in Gases

Name of Index	Per Ton of Output Capacity When the Gas Contains	
	3% $SO_2$	4.5% $SO_2$
Shop Production Costs, in rubles.....	129.52	143.79
In Which: Costs of Gas Processing, in rubles.....	34.13	53.84
Capital Expenditures per Capacity Unit, in rubles.	224.0	342.0

Table 5 continued

Name of Index	Per Ton of Output Capacity When the Gas Contains	
	8 % SO <sub>2</sub>	4.5 % SO <sub>2</sub>
Space Used per Capacity Unit, in cubic meters.....	0.661	1.50

As can be seen from the above data, when sulfuric acid is produced from converter gases, its shop production costs increase by 11.0 percent, unit capital expenditures -- by 52.5 percent, and space used per capacity unit -- more than twice. Thus, when raw charge is used without roasting, this not only entails the loss of a considerable quantity of sulfur (not less than 40 percent) but also deteriorates considerably all the principal indexes of sulfuric-acid production and increases more than one and one half times the capital expenditures on the organization of that production.

To justify the inexpediency of erecting a roasting shop at the Sredneural'sk Plant, L. M. Gazaryan cites data on the production costs of sulfuric acid which he had calculated upon taking into account the distance of its haul; he arrives at the conclusion that even if an in situ demand exists for that acid, the period of recoupment of the expenditures on building the roasting shop will last 11 or 12 years and it will reach 25 years if the demand exists at a distance of 500 kilometers away from the plant.

We do not know what basic data were used by L. M. Gazaryan in his calculations, but the results of these calculations diverge completely from the project data of the Giprokhim. According to calculations of the Giprokhim, the demand for sulfuric acid in the Urals, i. e., in the region of its production, will amount to no less than 1.8 million tons in monohydrate by the end of the seven-year period; therefore, the expenditures relating to its transport over large distances, as calculated by L. M. Gazaryan, will not exist.

The costs of the sulfuric acid produced from the metallurgical gases at the Sredneural'sk Plant and from the flotation pyrite, may, according to the data of the Giprokhim, be represented by the figures cited in Table 6.

Table 6

Production Costs of Sulfuric Acid Per Ton of Monohydrate

Site of Production of the Acid	Costs per Ton of Monohydrate in rubles	
	Shop Costs	Plant Costs
Sredneural'sk Plant (According to a Project, From the Gases of Metallurgical Production)	125.92	131.32
According to the Standard Pro- ject of the Giprokhim, From Flotational Pyrite.....	178.78	197.85
Voskresensk Chemical Combine	178.96	193.87

Considering that the present article is intended to demonstrate the erroneousess of L. M. Gazaryan's criticism of the currently materialized project for the modernization of the SUMZ, the writers did not deem it expedient to broach here the problems relating to the introduction in Ural plants of suspended-state smelting, cyclone smelting, and other new processes which may be the subject of a special article.

It can be seen from the above-examined features of the processing of copper-zinc concentrates under Ural conditions that the scheme adopted in the project of processing these ores at the Sredneural'sk Plant has been chosen correctly and, compared with the scheme of smelting concentrates in the raw form, displays the following advantages.

1. It ensures the regular metallurgical retreatment of high-zincous concentrates, which could not be done when they are smelted in raw form.

2. The comprehensiveness of utilization of the raw material increases considerably; in particular, the Sredneural'skiy Plant can obtain an additional large amount of sulfuric acid, and copper will be recovered to a fuller extent -- as will zinc and rare elements from the slags.

3. The sanitary-hygienic conditions in the region around the plant are improved drastically.

4. The technical-economic effectiveness of the Plant's activities improves substantially as a result of reduction in the consumption of fuel when hot roasted charge is smelted, increase in furnace productivity, decrease in the production costs of sulfuric acid when using rich gases, decrease in unit capital expenditures on sulfuric-acid production, and fuller recovery of copper, zinc, rare metals and particularly, sulfur.

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